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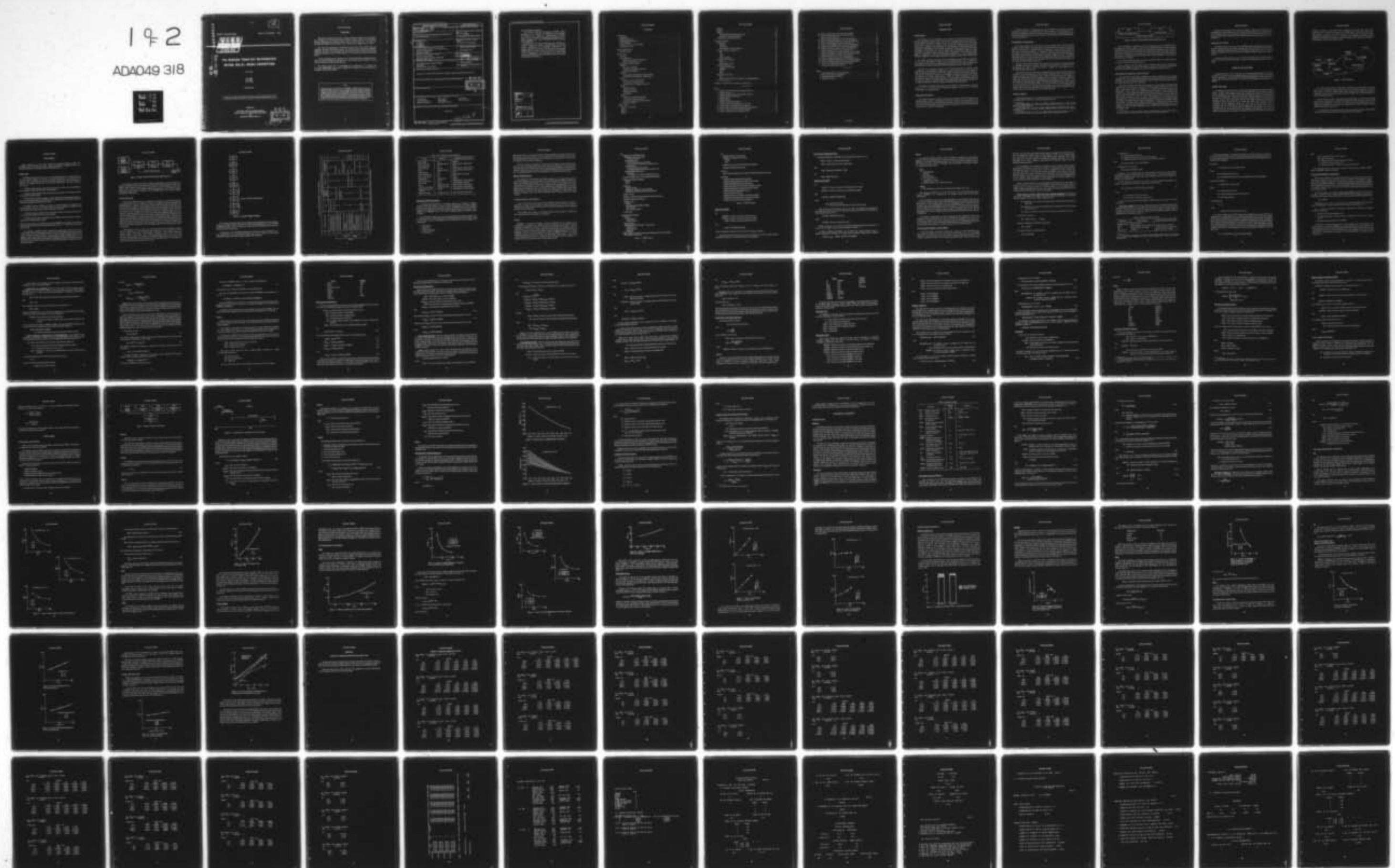

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THE MISSION TRADE-OFF METHODOLOGY (MTOM) MODEL: MODEL DESCRIPTION

Final Report

W.J. Strauss
N. D. Bailey
M. W. Kasper

December 1977

Prepared for

THE JOINT LOGISTICS COMMANDERS
JOINT TECHNICAL COORDINATING GROUP
ON
AIRCRAFT SURVIVABILITY

FOREWORD

This report summarizes the results of results of research performed by A. T. Kearney, Inc., Chicago, IL, for Aeronautical Systems Division (AFSC), Deputy for Development Planning, Wright-Patterson AFB, OH under contract F33615-74-C-5141. The work was performed from March 1974 to February 1975, and the project engineer was L. E. Boyd.

The work was sponsored by JTCG/AS as part of the 3-year TEAS (Test and Evaluation, Aircraft Survivability) program. The TEAS program was funded by DDR&E/ODDT&E. The effort was conducted under the direction of the JTCG/AS Survivability Assessment Subgroup as part of TEAS element 5.1.7.4, *Survivability Engineering Trade-Off Studies*.

A review of this report was conducted by J. L. Kemp, Naval Weapons Support Center, Crane, IN, under JTCG/AS task SA-6-02. As a result of that review, changes were made which are intended to enhance comprehension.

The authors would like to acknowledge the contributions of L. E. Boyd and R. K. Frick (ASD/XROL); also to their colleague M. A. Dloogatch for his contributions to the Mission Trade-Off Cost Model.

NOTE

This technical report was prepared by the Vulnerability Assessment Subgroup of the Joint Technical Coordinating Group on Aircraft Survivability in the Joint Logistics Commanders' organization. Because the Services' aircraft survivability development programs are dynamic and changing, this report represents the best data available to the subgroup at this time. It has been coordinated and approved at the JTCG subgroup level. The purpose of the report is to exchange data on all aircraft survivability programs, thereby promoting interservice awareness of the DOD aircraft survivability program under the cognizance of the Joint Logistics Commanders. By careful analysis of the data in this report, personnel with expertise in the aircraft survivability area should be better able to determine technical voids and areas of potential duplication or proliferation.

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The Mission Trade-Off Methodology (MTOM): Model Description, by W. J. Strauss, N. D. Bailey, and M. W. Kasper, A. T. Kearney Inc., Chicago, IL. Wright-Patterson AFB, OH, ASD, for Joint Technical Coordinating Group/Aircraft Survivability. December 1977. 114 pp. (JTCG/AS-76-S-001, publication UNCLASSIFIED.)

Presented are the results, assumptions and rationale of a model to evaluate the relative cost-effectiveness of proposed aircraft modifications for survivability enhancement. Two primary questions are addressed: how effective are the proposed modifications in a mission context and what are the important factors contributing to the improvement. To answer these questions, the MTOM model was developed. Parametric variations are presented and analyzed.

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INTRODUCTION

BACKGROUND

The reduction of the vulnerability of an aircraft to non-nuclear threats has been attained traditionally through retrofit modifications. This approach has been satisfactory in the past because survivability design criteria were not influential factors in the preliminary design phase of aircraft. For example, some aircraft were modified, based on combat experience, by adding improved self-sealing fuel cell bladders and internal reticulated foam to reduce the vulnerability of fuel systems. The retrofit of these items improved the overall survivability of the aircraft, but an even higher level of survivability might have been achieved if survivability design criteria had been incorporated in the preliminary design stages. In recognition of this, the JTCG/AS has embarked on a course of determining alternative feasible S/V (survivability/vulnerability) programs, as part of the TEAS program.

The utility of survival enhancement is not independent of the mission of the aircraft. In fact, some enhancement concepts may be counterproductive (e.g., an increase in survivability may be bought by trading payload for armor, but at the risk of requiring more aircraft sorties to destroy a target and possibly increasing the number of aircraft lost).

Another area in which the impact of S/V techniques should be evaluated is R/M (reliability and maintainability). Installation of passive protection may have an impact on R/M, in that the requirements for S/V add directly to the R/M burden of the aircraft. A common S/V technique is the provision of redundant systems (e.g., dual hydraulic systems for actuation of a flight control surface). While the added survivability of such an installation is apparent, the R/M requirement for two systems may be more than twice that for one (e.g., ceramic or transparent armor which cannot take repeated hits). Consequently, it usually is replaced after each hit, resulting in additional R/M requirements.

Side effects on aircraft performance, such as decreases in range, payload, speed and loiter time may accompany the increased survivability, and have to be evaluated quantitatively in a mission context.

PROBLEM DEFINITION

This report presents the results, assumptions and rationale of the development of a MTOM (mission trade-off methodology) model with which to assess the impact of S/V enhancement programs. This model provides measures of overall aircraft mission effects and cost, and provides comparisons of such enhancement programs. Analysis of some sensitivity computer runs is included in the appendix.

Pertinent measures of effectiveness, cost and cost-effectiveness, and some simplistic measures are presented in an earlier report[1]; a User's Manual[2] gives instructions for the input data for MTOM and presents a sample problem in its entirety; a classified supplement[3] presents weapons lethality data for enemy defenses. From these data PK (probability of kill) values can be obtained.

MTOM MODEL DESCRIPTION

The model calculates the LCC (life cycle costs) associated with a group of aircraft necessary to accomplish a prescribed mission. The fixed effectiveness for an air-to-ground mission is the delivery of a required number of weapons on a given number of targets in a given time. The model determines the minimum number of initial aircraft required to accomplish the prescribed effectiveness, and their costs. Interactions between the aircraft and various enemy defenses are simulated by following a flight of aircraft. Probabilistic calculations are made for the attrition and the ability of the aircraft to find the targets and deliver the weapons. Expected value calculations are made for the ground turnaround cycle of the aircraft to determine the sortie rate.

The costs include all aircraft losses and damage repairs as well as life cycle expenditures (i.e., RDT&E, procurement, training, operations and maintenance). Evaluations of S/V improvements are made by using the model to compute the total mission costs to accomplish the prescribed mission.

The model also can be used without considering costs to calculate the effectiveness of an aircraft, or its modification, for a given scenario. Parameters can be varied easily so that sensitivity analysis and investigation of the effects of uncertainties can be carried out readily. The model development is modular and can be extended or modified by addition or replacement of submodels. The overall MTOM model structure is shown in Figure 1. Two major submodels comprise MTOM: MTO/E (mission trade-off/effectiveness) model evaluates the number of aircraft required initially to do a fixed job; MTO/C (mission trade-off/cost) model calculates the LCC for the aircraft. Extensive use is made of probabilistic and expected value calculations. Maintenance, damage repair and ground turnaround are treated and their effects are extrapolated over time (length of the war).

SCOPE OF MODEL

The primary emphasis in the model development is on a fairly short war (e.g., 30 days); accordingly, killed aircraft are not replaced until after the war.

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[1]Caywood-Schiller Division, A.T. Kearney, Inc. *Measures of Effectiveness and Costs to Evaluate Aircraft Vulnerability Reduction Programs*, by W. J. Strauss and M. W. Kasper, Chicago, IL, September 1974. 18 pp. (Technical Report, publication UNCLASSIFIED.)

[2]Caywood-Schiller Division, A.T. Kearney, Inc. *Mission Trade-Off Methodology (MTOM) Model: User's Manual*, by W. J. Strauss, N. D. Bailey, and M. W. Kasper, Chicago IL, December 1974. 82 pp. (JTCG/AS-76-S-002, publication UNCLASSIFIED.)

[3]Caywood-Schiller Division, A.T. Kearney, Inc. *Mission Trade-Off Model (MTOM): Supplement 1* (U), by W. J. Strauss, N. D. Bailey, and M. W. Kasper, Chicago IL, December 1974. 10 pp. (Publication SECRET.)

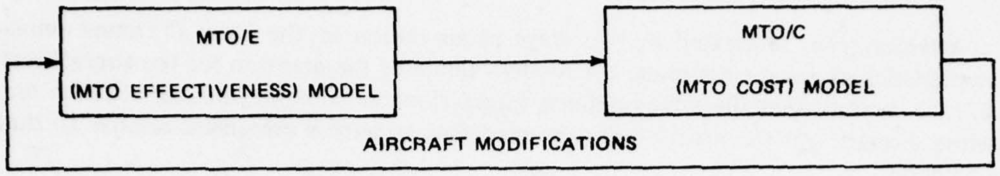


Figure 1. Mission Trade-Off Methodology Model Structure.

The overall MTOM is structured so that for a given aircraft type the MTO/E model is first applied and then the MTO/C model. Thus, the MTOM model is a fixed-effectiveness variable-cost model. This approach makes the model direct and simple since the number of aircraft lost in wartime are an important contribution to the total cost, and the number of aircraft lost is determined by the attrition and level of effectiveness required. By comparing the results for the standard aircraft with those of each design alternative, cost-effectiveness evaluations can be obtained.

The model evaluates the ability of a flight of aircraft to deliver a requisite number of weapons to a series of homogeneous targets.

In one computer run, the model cycles through the various aircraft configurations considered. The program starts with the baseline or standard aircraft and proceeds through the aircraft modification candidates; up to nine candidates can be treated in one run.

TREATMENT OF AIRCRAFT SURVIVABILITY

The aircraft sortie surviability calculations are made as a function of time along the flightpath. The use of exponential survivability calculations simplifies the model and limits the number of input parameters. Supportive effects of a flight of aircraft flying together to the same general target area are incorporated.

The effects of multiple defensive weapons firing at an aircraft are incorporated into the MTO/E model. Certain data is available from other agencies working on the JTCG/AS effort. These data include PK calculations of a single aircraft flying through a given deployment of given enemy guns. MTOM integrates these PK for various aircraft flight segments into an overall sortie survivability and attrition calculation. These PK tables were derived from HAVE LIME[4] data. The model treats enemy weapon mixes including those heavier enemy weapons not in the current TEAS program, but to which an aircraft realistically may be expected to be exposed in almost any mission. This approach permits the analyst to examine the survivability enhancement concepts and vulnerability implications against the lighter enemy weapons embedded in a background of mixed enemy defenses. As better JTCG/AS engagement PK for weapons become available, they can be substituted for HAVE LIME data (reference 4) or added without changing the structure of the MTO/E model.

[4]Air Force Systems Command. *HAVE LIME, A Study on Defense Suppression, Volume III - Systems Analysis* (U), Eglin AFB, FL AFSC, July 1972. 328 pp. (AFSC-TR-72-007, Volume III, Part 1, publication SECRET.)

Attrition can be treated in two ways as an option to the user: (1) based on input characteristics of enemy defenses, the model calculates the attrition for the aircraft sorties, or (2) the model tunes the attack-defense interactions to an input nominal attrition for the baseline aircraft and the attrition for the modified aircraft is calculated relative to that of the baseline.

TREATMENT OF COSTS

The MTO/C model treats future costs of RDT&E, aircraft modification or acquisition, peacetime operating cost and wartime operating cost. Thus, the model calculates absolute dollars. Incremental dollars associated with vulnerability improvements can be found by taking the differences between the costs for the basic aircraft and those for the modified aircraft.

A discount option enables the user to obtain the present value of future streams of money. For some decisions, this presents a useful way of comparing alternative courses of action.

MISSIONS AND SCENARIOS

Although the model can be used for any of several possible missions, the primary emphasis is on missions in the air-to-ground category. Of particular interest are interdiction and air superiority (i.e., air base attack). With some reinterpretation of certain events (recee, assault, cargo, CAS (close air support), or even air-to-air, including escort), missions can be handled.

SAMPLE SCENARIO

An outline of a particular kind of mission for a particular kind of scenario is shown in Figure 2. A flight of four aircraft, each armed with twelve M-117 bombs, takes off from an air base 150 km from the FEBA (forward edge of battle area). There is a small probability that an aircraft aborts early. Most aircraft cross the FEBA and penetrate enemy defenses at an altitute of 1200 meters at 200 m/sec. The enemy defenses consist of a mix of weapons including various AAA (antiaircraft artillery) guns, SAM (surface-to-air missile) and interceptors. Some aircraft may be hit; some even killed. Next, the flight reaches a checkpoint near the designated target area 175 km into enemy territory. There is a probability that an aircraft fails to find the target area. An aircraft which locates the checkpoint pops up at a 30 degree angle for 4,000 meters and searches for its particular assigned target. The individual targets for each member of the flight are in the same area. During the search phase, all aircraft are subjected to fire from local defenses. If the aircraft

identifies its target, it commences a dive at 30 degrees to track the target. The aircraft releases two M-117 weapons and swings away from the target to make another pass on the same target or go to the next assigned target. At the next target the process of target identification, acquisition, lock-on, etc., is repeated. After the flight of aircraft has made its assigned passes on all assigned targets, it flies back through an area defense at an altitude of 1200 meters, at 200 m/sec, homeward bound.

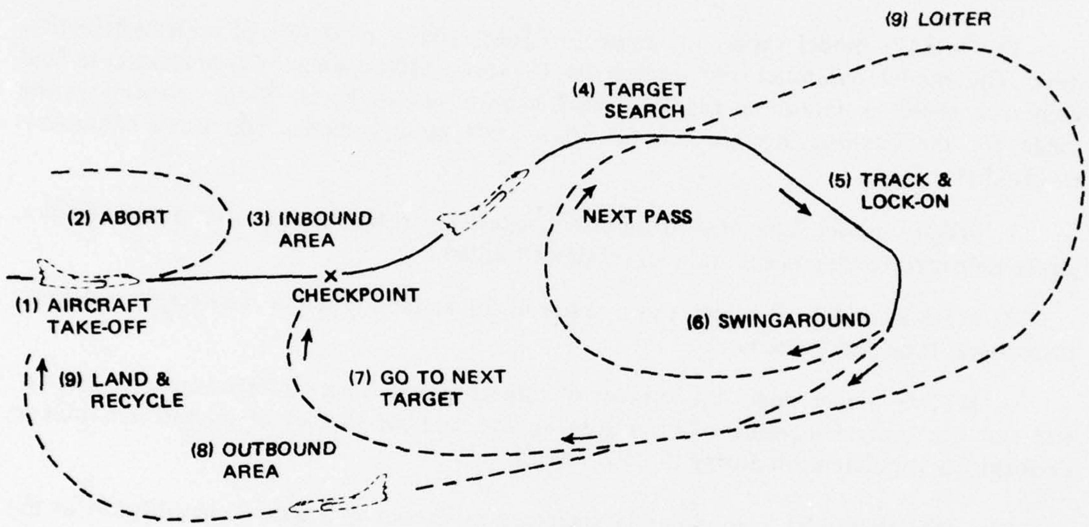


Figure 2. Typical Scenario.

If the aircraft fail to find the initial checkpoint because of poor navigation, they return home or go to an alternate target considered to be of secondary importance. An aircraft which fails to acquire an assigned target swings away from the target and awaits the completion of the passes by the other aircraft in the flight. The reconstituted flight then goes to the remaining targets.

Aircraft that survive the enemy defenses eventually return to home base. Post flight inspection and maintenance is conducted. Damaged aircraft are repaired by battle damage repair teams. Eventually, the aircraft are rearmed and become available for the next assignment. The same kind of missions are conducted (e.g., a period of 30 days, which is taken to be the length of the war).

The model treats all parts of this type of scenario, emphasizing those aspects directly related to survivability and affected by vulnerability reduction programs.

MTO/E MODEL

Some conventions of this section should be mentioned. Wherever possible the FORTRAN names for variables are used, usually suppressing the FORTRAN form of the subscripts. However, when helpful, algebraic subscripts are used.

STRUCTURE

The MOT/E model shows the impact of vulnerability reduction of mission effectiveness. The model computes the impact on (1) sortie effectiveness, (2) maintenance and combines these to determine (3) the overall mission effectiveness. These calculations are made for the baseline aircraft and for all aircraft modifications. The three submodels involved are:

1. MTO/P model calculates sortie effectiveness measures such as survival probabilities, passes delivered to targets and number of aircraft killed.

2. MTO/S model calculates times required for various types of maintenance, aircraft turnaround time and sortie rate.

3. MTO/F model calculates number of targets attacked per aircraft during the time of war and the general measure of effectiveness, the number (force) of aircraft required to perform the stipulated job during the war period.

The MTO/E model is modular in structure as shown in Figure 3. In addition to the three submodels, there are two others which act as preprocessors by making certain calculations for the baseline aircraft and modifications. These are:

1. MTO/D model is concerned with evaluating the effects of several aircraft subjected to fire from several different types of enemy defenses.

2. MTO/W model makes calculations which translate input weapons per target to assignments of weapon delivery passes.

Outputs from the latter two models are used by the MTO/P model, which in turn feeds the MTO/S model which then drives the MTO/F model. The last three models treat one aircraft type at a time.

The baseline or standard aircraft is treated in a special way if the user exercises a certain option. If the nominal attrition option is exercised, the MTO/E model first calculates certain parameters needed internally so that in fact the input nominal attrition of the baseline aircraft takes place. With the offense-defense interaction parameters set by the MTO/E model, all the necessary effectiveness calculations are made for the baseline aircraft and then for the modified aircraft so that the attrition of the latter is calculated relative to that of the former.

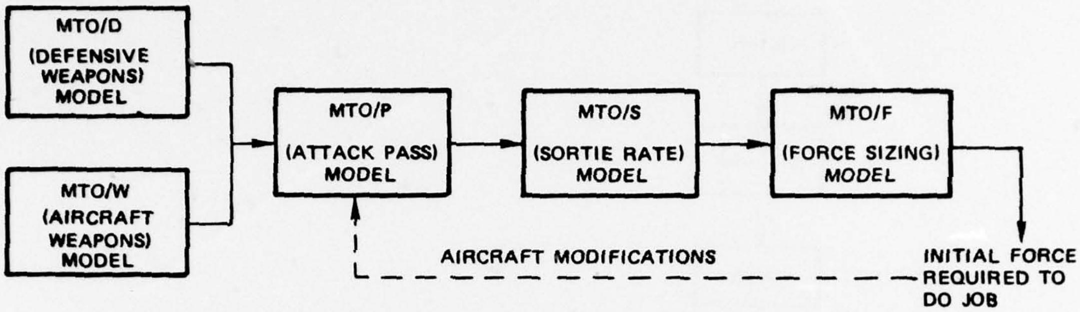


Figure 3. Mission Trade-Off Effectiveness Model Structure.

To examine the program listing, the computer program flow is shown in Figure 4. It follows the modular structure with additional modules for entering required input data. The JOBIN module handles general inputs. Inputs related to the treatment of the many aircraft–many defense types (MTO/D submodel) are handled by the MTODIN module. Maintenance related inputs are treated by the MTOSIN module. The routine sub-MOE calculates the submeasures.

EVENT SEQUENCE

Central to the MTO/E model is the simulation of the sequence of events which describe an aircraft sortie as part of a flight. The sequence is utilized in submodels MTO/D and MTO/P (Figure 2). A flight of aircraft takes off and travels to the FEBA. Aircraft aborts are removed from the flight size. The aircraft then proceed to a checkpoint to locate the target area. If the area is located (no gross navigational error exists), the flight of aircraft continues its mission. If not, the flight returns home (or diverts to a secondary target area of no interest). Continuing aircraft pop up to search for their specific assigned targets. An aircraft which locates its target dives to attack the target and then swings around. If more than one pass is to be attempted, the aircraft climbs, dives and swings around again. This process is repeated until the required number of passes have been completed. Those individual aircraft that do not locate the specific target loiter until all passes are completed by the others. The flight then reforms and proceeds to the next target. The search, attack and possible loiter events are repeated at each target. After all assigned targets have been attacked, the aircraft return home.

This sequence of events is fixed; it is most representative of an interdiction mission. However, variations in input parameters yield sequences of events descriptive of other missions. Table 1 shows how a reinterpretation of specific events permits evaluation of various missions: CAS, strike recce, defense suppression, photo recce, escort ECM (electronic countermeasures), spotting or controlling as forward observer and air-to-air. The table also indicates which events are looped over for delivering passes to a given target and which events are looped over for targets on a sortie.

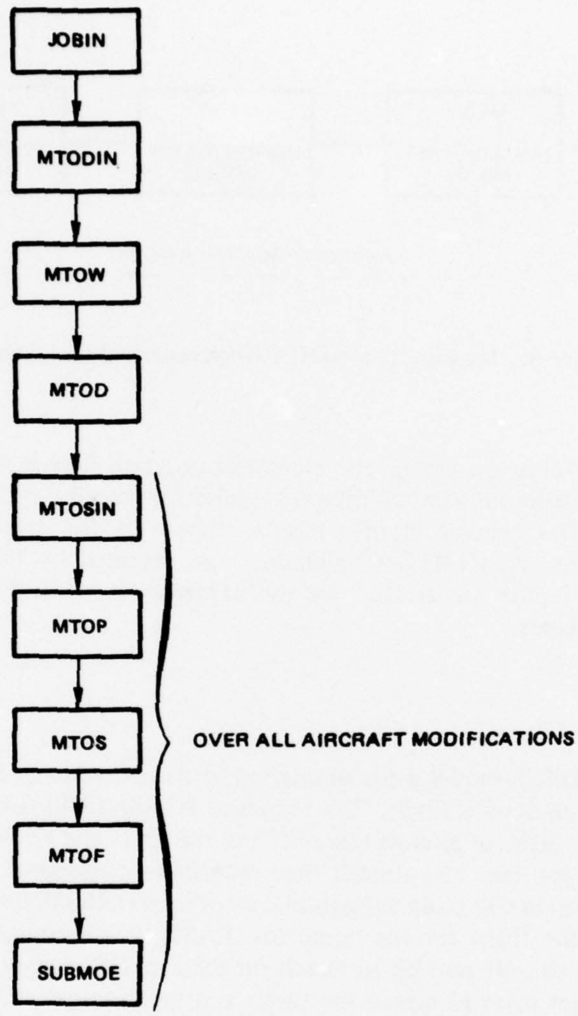


Figure 4. Computer Program Structure.

The number of targets attacked and the number of passes attempted at each target are computed by MTO/W. Other characteristics of this mission flightpath are input in JOBIN and MTODIN. Table 2 shows the sequence of events, the associated maneuver, and the input parameters which describe them.

All parameters except PRABR (probability of aircraft abort), PNAV (probability of no gross navigational error), and XIFS (the flight size), can be varied for each aircraft modification. Speeds on different profile segments may be different.

Table 1. MTO/P Applicability to Various Missions.

	Event	Interdiction event name	New event names for other missions				
			CAS	Strike recce or defense suppression	Photo recce	Escort ECM spotting or controlling	A→A
	3.	Aircraft reaches target area	Reaches orbit area	X	X	X	X
	3.1	Aircraft survives this event	X	X	X	X	X
	3.2	Aircraft locates target area	Finds orbit area	X	X	X	X
Targets	4.	Aircraft reaches assigned target	X	Searches for target	X	Or orbit area	X
Targets	4.1	Aircraft survives this event	X	X	X	X	X
Targets	4.2	Aircraft locates assigned target	X	If target exists, locates target	X	Orbits	X
Targets / Loiter	4.	Aircraft (fails to locate target and loiters)	X	X	X	Or fails to find orbit area and loiters)	X
Targets / Loiter	4.1	Aircraft survives this event	X	X	X	X	X
Targets / Passes	5.	Aircraft reaches launch point	X	X	Flies prescribed path	Orbits	A→A:X
Targets / Passes	5.1	Aircraft survives this event	X	X	X	X	A→A:X
Targets / Passes	5.2	Aircraft locks-on and launches weapon	X	X	Completes path	Orbits	A→A:X
Targets / Passes	6.	Aircraft swings around for next pass or leaves target	X	X	X	Continuous orbiting	A→A:X
Targets / Passes	6.1	Aircraft survives this event	X	X	X	X	A→A:X
Targets	7.	Aircraft flies to next target	Round trip to loiter area	Resumes search	X	Or next orbit area	A→A:X
Targets	7.1	Aircraft survives this event	X	X	X	X	A→A:X
	8.	Aircraft flies home	X	X	X	X	X
	8.1	Aircraft survives this event	X	X	X	X	X

Note: See Figure 2; A→A = air-to-air; an X indicates no change is needed for the name of the event in a given mission.

Table 2. Events, Maneuvers, and Parameters.

Event	Manuever	Applicable input parameters
Reach FEBA	N/A	PRABR
Reach checkpoint	Straight and level	Speed, altitude, distance/time
Locate target area	N/A	PNAV
Climb to search	Pop-up	Initial altitude, terminal altitude
Search	Straight and level	Speed, altitude, distance/time
Target location	N/A	PLOC
Dive to launch point	Dive	Initial altitude, dive angle
Lock on and launch	N/A	BETA
Swingaround	Swingaround	Altitude
Climb to dive again	Pop-up	Initial altitude, terminal altitude
Dive to loiter	Dive	Initial altitude, dive angle
Loiter	Straight and level	Speed, altitude, distance/time
Proceed to next target	Straight and level	Speed, altitude, distance/time
Climb to homebound altitude	Pop-up	Initial altitude, terminal altitude
Homebound flight	Straight and level	Speed, altitude, distance/time

Defense Links With Event Sequence

To evaluate the effectiveness of vulnerability reductions, the lethality of defensive weapons encountered during a sortie is treated. Characteristics of weapons possibly encountered are input (see *General Inputs* for more detailed descriptions). The characteristics are quite general and not related to specific gun placements. Consequently, many variations in a flightpath may be run with no changes required in defensive weapon population.

It is reasonable to expect that, for example, weapons encountered in a target area will be different or more numerous than those encountered inbound or outbound. The concept of four defense zones is incorporated into the model which can be thought of as representing:

1. Inbound area
2. Target local
3. Between target area
4. Outbound area

Relating the defense zones to the defense weapons population are densities which specify the quantity per square kilometer of a given weapon to be encountered in a given zone. Using these densities a specific weapon can be decreased or even shut off in a certain zone; or conversely, can be made more numerous.

The link connecting the defense zones to the event sequence consists of input codes which tie each event during which the aircraft is subject to attrition to a specific defense zone. This device offers another method for varying a mission definition. For example, it is possible to associate an attack event, such as lock-on and launch, with target local defenses (e.g., for bombing mission) or with an area defense (e.g., for stand-off missile launch).

Model Cycling Over Events

The approach of both MTO/D and MTO/P models is to cycle over the sequence of events and accumulate necessary quantities for their computations. MTO/D computes the effects of multiple weapons firing at an aircraft for each of the sequence of events. Computations are performed for the baseline aircraft and for all modifications. There is the input option in this submodel which scales modifications survivability relative to an input attrition for the baseline aircraft. (See *MTO/D* for details). MTO/P takes results from MTO/D (scaled or not) and cycles them through the event sequence, accumulating various quantities including aircraft lost, passes completed, aircraft returned home and passes returned.

GENERAL INPUTS AND OUTPUTS

A list of most of the inputs required by the MTO/E model is displayed in Figure 5. Definitions of terms and the manner in which the inputs are used by the model are presented later in this report. The complete list of inputs is presented in the User's Manual (reference 2) with their format.

A brief listing of the outputs of the MTO/E model is shown in Figure 6. Sample input data is shown as part of the outputs in the appendix.

MTO/W

MTO/W is a preprocessor model. It makes calculations for the baseline and all modifications at the same time. MTO/W uses input aircraft weapon carrying and delivery capabilities and WPNTGT (number of weapons to be expended at each target) to generate characteristics of the mission profile. The output characteristics are TGTSOR (number of targets to be attacked per sortie) and PASTGT (number of passes attempted at each target). WPNSOR (number of weapons carried per sortie) and WPNPAS (number of weapons expended per pass) are the aircraft inputs to this sub-model. Inputs may be varied for each aircraft modification; however, it is assumed that the weapon carrying capability of a modification is never greater than that of the standard aircraft.

S/V
- TABLES OF KILL PROBABILITIES[a]
  - STRAIGHT AND LEVEL FLIGHT
    - By Speed and Altitude
  - POP-UP MANEUVER
    - By Initial Altitude and Terminal Altitude
    - Fixed Angle of Climb and Speed (determined by user)
  - DIVE MANEUVER
    - By Initial Altitude and Dive Angle
    - Fixed Speed and Pullout Altitude (determined by user)
  - SWINGAROUND MANEUVER
    - By Altitude
    - Fixed Speed and Turn Duration (determined by user)
- RATIO OF DAMAGE-TO-KILL FOR STANDARD AIRCRAFT
- DENSITY OF ENEMY DEFENSES
  - REGION
  - TYPE
- FIXED JOB
  - LENGTH OF WAR
  - NUMBER OF TARGETS TO BE ATTACKED
  - NUMBER OF WEAPONS REQUIRED PER TARGET
- SORTIE LENGTH
- NOMINAL ATTRITION FOR STANDARD AIRCRAFT (optional)
- NUMBER WEAPONS PER SORTIE[a]
- PROBABILITIES
  - ABORT
  - NO GROSS NAVIGATIONAL ERROR
  - FIND TARGET[a]
  - LOCK-ON AND TRACK[a]
- FLIGHT SIZE

MAINTENANCE & SUPPORT
- MMH/FH
  - SCHEDULED[a]
  - UNSCHEDULED[a]
- MMH/DAMAGE[b]
- CONVERSION FACTORS: MMH → CLOCK TIME
  - SCHEDULED[a]
  - UNSCHEDULED[a]
  - DAMAGE[a]

[a]May be different for baseline aircraft and each modification within one run of the program.
[b]Time to inspect, rearm, wait, etc.

Figure 5. MTO/E Input.

S/V
NUMBER AIRCRAFT LOST IN WAR
PROBABILITY AIRCRAFT SURVIVES
SORTIE
WAR

DAMAGE-TO-KILL RATIO FOR MODIFIED AIRCRAFT

NUMBER DAMAGES PER AIRCRAFT

OVERALL
WAR FORCE (NUMBER INITIAL AIRCRAFT REQUIRED TO DO FIXED JOB)

SCENARIO
NUMBER TARGETS ASSIGNED PER SORTIE
NUMBER PASSES ASSIGNED PER SORTIE PER TARGET
NUMBER WEAPONS DELIVERED PER SORTIE
NUMBER WEAPONS LOST ON KILLED AIRCRAFT IN WAR
NUMBER WEAPONS DELIVERED ON TARGET IN WAR
NUMBER WEAPONS RETURNED IN WAR
SORTIE RATE PER AIRCRAFT
NUMBER SORTIES AVAILABLE IN WAR PER AIRCRAFT
NUMBER SORTIES COMPLETED IN WAR PER AIRCRAFT
NUMBER TARGETS ATTACKED PER SORTIE

Figure 6. MTO/E Output.

Derivation of IPASS

Let

WPNSOR = Number of weapons carried per sortie
WPNPAS = Number of weapons expended per pass
IPASS = Number of passes attempted per sortie

then

$$IPASS = [WPNSOR/WPNPAS]$$

where [ ] indicates the integar part of the number enclosed in brackets.

The inputs should be such that the ratio is an integer. If it is not, the model makes an adjustment for this error, and continues with its computations.

Correction for Possible Input Error

If (IPASS) (WPNPAS) < WPNSOR, then not all weapons will be used. Let

WBH = Number of weapons brought home

PBH = Fractional part of a pass brought home

then

$$PBH = (WPNSOR)(WPNPAS) - IPASS$$

and

$$WBH = (PBH)(WPNPAS)$$

Derivation of PASTGT

Let

PASTGT = Number of passes to be attempted at each target

WPNTGT = Number of weapons to be expended per target

then

$$PASTGT = \langle WPNTGT/WPNPAS \rangle$$

where

$$\langle Q \rangle = \begin{cases} Q \text{ if } Q \text{ is an integer.} \\ \text{The next integer larger than } Q\text{, if } Q \text{ is not an integer.} \end{cases}$$

Here again, the inputs should be such that the ratio is an integer if it is intended that each target receive the same number of passes from a given aircraft. However, the model can treat anomalies in this manner:

$$TGTSOR = \langle PASSRT/PASTGT \rangle$$

where

TGTSOR = Number of targets per sortie

IPASS is allocated to the targets to be attacked. Targets are assigned equal numbers of passes with the possible exception of the last target to be attacked.

If IPASS = (PASTGT) (TGTSOR), then all targets are assigned PASTGT passes. If IPASS < (PASTGT) (TGTSOR), then the last target is assigned a smaller number of passes.

$$PASTGT_{LAST} = IPASS - (PASTGT)(TGTSOR-1)$$

MTO/D

The submodel, MTO/D, performs initial survivability computations for the standard aircraft and for all modifications for a specific scenario as part of the preprocessor. The flightpath is defined by input parameters and by the results of MTO/W. Additional inputs are required to define aircraft vulnerability and the lethality of defensive weapons encountered during the mission.

Input:

1. Flightpath data
2. PK tables
3. DEN (D-factor)
4. ATT (attrition level)
5. Vulnerability fractions
6. GAMMA (defense zone attrition allocation)

Output:

1. PN (probability of survival for a single aircraft for flight size of one)

The purpose of MTO/D is to produce PN for use in the submodel MTO/P. These survival probabilities are computed for the baseline aircraft and for all aircraft modifications.

PN are calculated in one of two ways, depending on an input option. If the user does not select the attrition scaling option (OPT=FALSE) the aircraft survival probabilities are based solely on the defensive weapon–aircraft vulnerability inputs. In this case, the PT (tentative event survival probabilities) are used for the PN. If the user, however, chooses to use the scaling option (OPT=TRUE), PN are then based on an ATT input for the baseline aircraft as well as on the defensive weapon–aircraft vulnerability data; for this case the computation of PT and the additional scaling computations are discussed (see *Event Survival Probabilities*).

The attrition scaling option is introduced because attrition probabilities computed in models are often unrealistically high. Since in MTOM the probabilities are used in other submodels to compute sortie rates, maintenance data and cost-effectiveness evaluations, a lack of realism may severely distort results. The attrition option in MTOM allows the user to place all results in the context of a realistic attrition rate for the baseline aircraft.

Event Survival Probabilities, Absolute Option

As described earlier, the mission is defined by a sequence of events. MTO/D evaluates the aircraft survivability for each event during which attrition can occur. Survivability depends on the aircraft behavior and the defensive weapons encountered during the event. Defensive weapons are defined by the weapons population and the defense zone associated

with the event. There are four possible aircraft maneuvers: straight and level flight, pop-up, dive, and swingaround (Table 2). The model associates a specific type of maneuver with each event (fixed, not input). Defensive weapon lethality inputs are categorized by these four maneuvers for each weapon in the defensive weapons population. The survival probability of an event is computed using the links of maneuver, defense zone, and defensive weapon population.

The methodology for evaluating the lethality of each defensive weapon involves development of PK values for one aircraft attacked by one defensive weapon (one-on-one). The expected number of weapons for each event is calculated and used to expand the one-on-one PK values to an appropriate survival probability for an entire event. This approach allows the flexibility of using one set of PK values for various weapon densities and event lengths. Use of this approach permits computation of the survival probability for an event without specific knowledge of weapon placements and makes it possible to run many scenarios with minimal changes in input parameters.

Values of PK developed for one aircraft attacked *simulataneously* by *more than one* weapon (one-on-one) can also be used in MTOM. In this case, the expected number of weapons must be changed to reflect the expected number of sets of weapons used to develop the PK values. PK values for sets of one-on-one encounters generally will not be as useful as individual PK values for one-on-one encounters.

DERIVATION OF EVENT SURVIVAL FOR A SINGLE AIRCRAFT. The derivation will first be accomplished for a single weapon type and then generalized over all weapon types (one through J). For a given defense weapon type, let

PS = Probability of one aircraft surviving an event when subjected to weapons of a given type

PK = Probability of an aircraft being killed by one defensive weapon of the given type (one-on-one)

M = Expected number of weapons of the given type encountered in an event

The PS may be written as:

$$PS = (1\text{-}PK_1)(1\text{-}PK_2)\ldots(1\text{-}PK_M)$$

Using the assumption that all PK are equal, then

$$PS = (1\text{-}PK)^M$$

The value of PS can be approximated by:

$$PS \simeq \exp\text{-}(M)(PK) \qquad (1)$$

To obtain M, let

d = Event length (kilometers)

R = Maximum effective ground range of the weapon

ρ = Density of defensive weapons (quantiy per square kilometer)

then

$$M = \text{Area x density} = [(d)\,(2R/1000)]\,(\rho)$$

Consequently, Eq. 1 becomes

$$PS \simeq \exp\text{-}(d)\,(2R/1000)\,(\rho)\,(PK)$$

The value of d is obtained from the flight profile data. The value of the quantity $(2R/1000)\,(\rho)$ is input to the model as the variable D-factor. Values of PK generally are obtained by averaging results from models, such as P001[5], over a variety of specific gun placements or offset ranges.

The PT obtained by combining the effects of multiple weapons (assumption: all defensive weapons are concentrated on a flight size of one aircraft) is:

$$PT = \prod_{j=1}^{J} (PS)_j \simeq \exp(-0.002d) \sum_{j=1}^{J} (\rho_j)\,(R_j)\,(PK)_j \qquad (2)$$

where

j = The defensive weapon type index

J = The number of defensive weapon types

For the case of absolute attrition (OPT=F), MTO/P equates the value of PN to the value of PT.

USE OF PK TABLES. MTO/D requires PK information for each defensive weapon and for each aircraft maneuver for the baseline aircraft. These data are input as tables with the headings as shown in Table 3. While PK values are input as tables, the input values for parameters are not restricted to those of table headings. Interpolation routines provide the appropriate PK for the input parameters.

Table 3. Headings for PK Input Tables.

Maneuvers	Table headings	Implicity fixed by input table
Straight and level	Speed, altitude	
Pop-up	Initial altitude, terminal altitude	Climb angle, aircraft speed
Dive	Initial altitude, dive angle	Terminal altitude, aircraft speed
Swingaround	Altitude	Radius of turn, *g*'s pulled

[5]Air Force Armament Test Laboratory. *Anti-Aircraft Artillery Simulation Computer Program - AFATL Program P001*, by J. Severson and T. McMurchie. Eglin AFB, FL, AFATL. September 1973. (TN 4565-16-73, publication UNCLASSIFIED.)

From the formulation it is apparent that distance traversed is required to compute a survival probability for each event. For straight and level cases, either this distance (km) or a time (sec) must be specified. For other maneuvers the distances and other pertinent data are computed by the model, as:

For pop-up:

$$d = (0.001)\,((A_T - A_I)/\sin\text{(climb angle)})$$

where

A_T = Terminal altitude (meters)

A_I = Initial altitude (meters), and climb angle (fixed-currently 30 degrees)

For the dive maneuver:

$$d = (0.001)\,((A_I - A_T)/\sin(D))$$

where

A_I = Initial altitude (meters)

A_T = Terminal altitude (fixed-currently 150 m)

D = Dive angle (degrees)

For swingaround:

$$d = 2\pi r$$

where

r = Radius of turn (fixed-currently 2 km)

For aircraft modifications, the PK changes can be effected in two ways. PK tables, if available, can be specifically input for maneuvers and weapons; if such tables are not input, PK for aircraft modifications are assumed to be those for the baseline aircraft. Vulnerability factors (B) may also be used to represent vulnerability reductions for aircraft modifications. These factors are assumed initially by the model to one, but through inputs may be changed (e.g., if the ith aircraft modifications is expected to result in a 10% vulnerability reduction (actually PK reduction) to the jth weapon, then the corresponding vulnerability factor (B) would be input as 0.9). The formulation for aircraft modification survivability of an event (Eq. 2) is:

$$PT = \exp\left\{-(0.002)\,(d)\sum_{j=1}^{J}(R_j)\,(\rho_j)\,(B_j)\,(PK_j)\right\} \qquad (3)$$

where

B_j = Vulnerability factor for jth weapon

PK_j = PK for jth weapon

R_j = Maximum effective ground range of jth weapon

d = Penetration distance during event

ρ_j = Density of weapon in defense zone associated with event

PT calculations for each event are performed by the computer subroutines COMPT, SURV1 and SURV2, FIND1, and FIND2.

Event Survival Probabilities, Scaled Option

There are many elements of the interactions between the defense and offense that are difficult to incorporate into the input PK values (e.g., problems of firing doctrine, reaction time, terrain masking, training level of personnel and amount of ammunition available). Thus, PT values obtained from Eq. 3 are sometimes biased lower than combat experienced survival probability (historical data). For present purposes, these interactions do not have to be modeled in detail. There is an option to tune these attack-defense interactions to an input nominal attrition.

If the user utilizes the attrition scaling option (OPT=T), scaling of PT values is necessary to obtain the values of PN needed by MTO/P. If OPT=F, SCAL (scaling factor for the given event) equals one and PN equals PT. The scaling option (OPT=T) takes the form,

$$PN = PT^{SCAL} \tag{4}$$

Referring to Eq. 3 it can be seen that use of an exponential SCAL is effectively the same as modification of weapon densities or of PK values for a particular event.

It now remains to obtain an appropriate formulation for SCAL. The following derivation is based upon:

1. The input ATT for the baseline aircraft
2. The relative lethality of various events as expressed by the PT for the baseline aircraft
3. An optional input distribution of GAMMA.

The attrition scaling option allows the user to allocate the input attrition to the defense zones by using input GAMMA (e.g., he could allocate 70% of the attrition to the local target defenses, 15% to between-target defenses, 10% to inbound area defenses and 5% to outbound area defenses). If the zonal allocation is not specified by the user, the model will make its own allocations according to the tentative attrition it calculates for each defense zone.

To derive SCAL, two preliminary steps are required: an allocation of attrition and the calculations of event survival probabilities.

ALLOCATION OF ATTRITION. There are many ways to define the event survival probabilities so as to yield the nominal ATT. The model uses event GAM (attrition allocation factors) to compute event survival probabilities in a natrual way. These factors sum to one. Let

PTK = Pr (aircraft is killed during event, given aircraft survived up to event)

then

PTK = 1-PT

Now consider the defense zone associated with the event of interest. Let

SUM = ΣPTK

where the summation occurs over all events in the defense zone. Then PR (aircraft is killed during event, given aircraft is killed in zone) $\simeq$ PTK/SUM. Let

GAMMA = Input defense zone attrition allocation

= Pr (aircraft is killed in defense zone, given aircraft is killed on the sortie)

If no zone allocation is input, GAMMA is defined to be one and SUM is summed over all events in the scenario. Therefore, the event attrition allocation is given by:

GAM = (PTK/SUM) (GAMMA)

$\simeq$ Pr (aircraft is killed during event, given aircraft is killed on sortie)

EVENT SURVIVAL DERIVATION OF PROBABILITIES. After GAM have been ascertained, it is possible to compute event survival probabilities for the baseline aircraft. These probabilities when combined over the total flightpath will yield the input ATT.

Event survival probabilities are sequentially computed using GAM. Let

ATT = Input nominal baseline attrition (multiple aircraft per flight)

PC = Pr (aircraft survives up to a given event)

SURV = Probability of survival of a single aircraft in an event, multiple aircraft per flight

For inbound flight (first event during which attrition can occur),

PC = 1

Hence, Pr (aircraft killed during inbound flight)

= (GAM) (ATT) = (PC) (1-SURV) (5)

therefore

$$\text{SURV} = 1 - \frac{(\text{GAM})(\text{ATT})}{\text{PC}}$$

For the next event

$$\text{PC}_{next} = (\text{SURV})(\text{PC})$$

and

$$\text{SURV}_{next} = 1 - \frac{(\text{GAM}_{next})(\text{ATT})}{\text{PC}_{next}} \tag{6}$$

SCAL. SCAL will be used to convert values of PT for baseline into values of PN for baseline and PT values for modified aircraft into PN values for modified aircraft. This scaling is necessary to convert aircraft losses to the input ATT for baseline and to obtain attrition values for the modified aircraft that are relative to the input baseline attrition. Note: PT is absolute, PN is attrition scaled, both infer flight size of one.

SURV as calculated in Eq. 6 can now be used to compute SCAL. The ATT is expressed within the context of a flight size (i.e., the effects of multiple aircraft are included in its value). Since SURV is based on ATT, SURV also contains the effects of multiple aircraft per flight. MTO/D evaluates this multiple aircraft effect by a dilution concept which assumes that the defensive weapons are equally divided among each of the aircraft within the flight. This dilution concept has the same effect as changing the expected number of defensive weapons (M) in Eq. 1. The values of PN and PT are based on the assumption that all defensive weapons in an event are concentrated on one aircraft.

The dilution concept is:

$$\text{PN} = (\text{SURV})^{N} \tag{7}$$

The variable N represents the number of aircraft in the flight that have survived up to the event of interest. Combing Eq. 4 and 7 yields:

$$\text{PN} = \text{PT}^{\text{SCAL}} = (\text{SURV})^{N} \tag{8}$$

The following equation is obtained by solving Eq. 8 for SCAL; note SCAL is event dependent.

$$\text{SCAL} = (\text{N})(\log \text{SURV})/(\log \text{PT})$$

The value of SCAL is computed for the baseline values of SURV and PT and then applied to PN for a MOD (modification) candidate as:

$$\text{PN(MOD)} = [\text{PT(MOD)}]^{\text{SCAL}}$$

The value of PN(MOD) is obtained from Eq. 3.

The value of PT(MOD) from Eq. 7 is used to calculate SURV(MOD) as:

$$SURV(MOD) = [PN(MOD)]^{1/N} \tag{9}$$

The variable N in Eq. 9 represents the flight size for modified aircraft.

The value of SURV(MOD) is then used to calculate ATT(MOD) via a rearrangement of Eq. 5 as:

$$ATT(MOD) = [PC(MOD)]\,[1\text{-}SURV(MOD)]/GAM(MOD)$$

Thus, ATT(MOD) has been scaled to a value relative to the input ATT for the baseline aircraft. The value of SCAL is then used to convert PT (baseline) to PN (baseline) and PT(MOD) to PN(MOD).

Computations for scaling factors are performed by the routines COMSC, GM, and SCAL. The routine COMPN scales the tentative survival probabilities for use by MTO/P.

MTO/P

MTO/P produces several outputs for a given aircraft needed by MTO/S and MTO/F based on the aircraft performance during a sortie. Results include survival probabilities and passes completed.

The outputs are computed for the baseline aircraft or aircraft modification candidate by cycling through the sequence of events discussed previously and accumulating the necessary quantities using results from MTO/D and MTO/W and inputs from JOBIN.

The recursive relationship for the general events involving attrition and special cases which modify the procedure are presented. Basically, MTO/P updates several accumulators after each event. These accumulators involving aircraft and passes are:

ACH = Aircraft which return home prematurely
ACK = Aircraft which are killed
ACR = Aircraft which survive

The sum of ACH, ACK, and ACR is XIFS (number of aircraft on a flight). Accumulators for passes are:

PD = Passes delivered
PH = Passes brought home
PL = Passes lost

The sum of PD, PH, and PL is XINP (number of passes carried by the flight).

Inputs	Outputs
BETA	ACH
PLOC	ACK
PN for each event	PD
PNAV	PH
PRABR	PL
XIFS	PS
XINP	RWA
WPNPAS	

Derivations for General Events

At each event during which attrition can occur, several computations are made. Letting "old" and "new" subscripts indicate pre and post event values, define

ACR_{old} = Expected number of aircraft surviving up to event

ACK = Expected number of aircraft killed

AVP = Expected number of available passes

PL = Expected number of passes lost

PN = Pr (single aircraft survives event, flight size of one), an input from MTO/D

SURV = Pr (aircraft survives event - multiple aircraft per flight).

Let

$$XACR = \text{Max}\ (1, ACR_{old}) \qquad (10)$$

Then, the following relationships hold for a given event involving attrition.

$$SURV = (PN)^{1/XACR} \qquad (11)$$

$$ACR_{new} = (ACR_{old})\ (SURV) \qquad (12)$$

$$ACK_{new} = ACK_{old} + (ACR_{old})\ (1\text{-}SURV) \qquad (13)$$

$$AVP_{new} = (AVP_{old})\ (SURV) \qquad (14)$$

and

$$PL_{new} = PL_{old} + (AVP_{old})\ (1\text{-}SURV) \qquad (15)$$

Note that the updating of aircraft and pass status are made after the corresponding survivability information is calculated. A similar logic is used when calculations are made of passes delivered, targets identified, etc. In all cases, first the survivability of the aircraft during the event is computed and then the accumulators are updated.

These recrusive relationships, Eq. 10 through 15, hold for most events except for a few special ones involving either no attrition or branch points.

Derivations for Special Events

Several events involve slight modifications to this procedure. Before the aircraft reaches the FEBA, aborted aircraft are removed from the flight and the number of passes brought home is removed from available passes. These calculations are made as follows if:

$XIFS$ = Initial flight size, an input to MTOM

$PRABR$ = Pr (aircraft aborts), an input to MTOM

ACH_{abort} = Expected number of aircraft home due to abort

$XINP$ = Initial number of available passes on flight, an input from MTO/W

PH_{abort} = Expected passes returned home due to abort

then

$$ACR_{new} = (XIFS)\,(1\text{-}PRABR) \tag{16}$$

This becomes ACR_{old} for the next event (inbound attrition) treated by Eq. 12, and

$$AVP_{new} = (XINP)\,(1\text{-}PRABR) \tag{17}$$

This becomes AVP_{old} for the next event (inbound attrition) treated by Eq. 14. Also

$$ACH_{abort} = (XIFS)\,(PRABR)$$

and

$$PH_{abort} = (XINP)\,(PRABR)$$

PNAV BRANCH POINT. After the inbound segment, the flight of aircraft find the checkpoint in the target area if no gross navigational error occurs (case 2). If none of the aircraft locate the area, it is assumed the whole flight returns home (case 1). (The flight may go to secondary targets, but as far as the fixed job is concerned, the effectiveness counts as though the flight returns home.) Probabilities and expected values are computed for both possibilities at this branch point; the expected values are then weighted by the probabilities of their occurrences.

Case I. Let the subscript "in" refer to values associated with the inbound event, and "GNE" to the values related to the outbound event of aircraft returning home due to gross navigational error. Consider the situation in which the flight of aircraft does not locate the target area and returns home. This occurs with probability,

Pr (gross navigational error) = 1-PNAV

where

PNAV = Pr (aircraft navigates successfully to checkpoint), an input to MTOM

Let

$$SURV_{GNE} = Pr \text{ (aircraft survives homebound event)}$$

By developments similar to those in Eq. 10 through 15 for this particular event, let

$$XACR = Max\ (1, ACR_{in})$$

then

$$SURV_{GNE} = PN^{\frac{1}{XACR}}$$

$$ACH_{GNE} = (ACR_{in})\ (SURV_{GNE})\ (1\text{-}PNAV)$$

$$ACK_{GNE} = (ACR_{in})\ (1\text{-}SURV_{GNE})\ (1\text{-}PNAV)$$

$$PH_{GNE} = (AVP_{in})\ (SURV_{GNE})\ (1\text{-}PNAV)$$

$$PL_{GNE} = (AVP_{in})\ (1\text{-}SURV_{GNE})\ (1\text{-}PNAV)$$

Also let

ACH = Expected number of aircraft which return home prematurely

PH = Expected number of passes which are brought home prematurely

then

$$ACH = ACH_{abort} + ACH_{GNE}$$

$$PH = PH_{abort} + PH_{GNE}$$

Case 2. If no gross navigational error occurs, ACR_{old} aircraft continue the mission. Eq. 10 through 17 are applied iteratively for the ensuing events. The values calculated for the last event, returning to home base, are then multiplied by PNAV as the weighting factor for the sequence of events initiated by the flights successful navigation to the checkpoint.

PLOC BRANCH POINT. After the aircraft reach the target area and search for the target, another possible branch occurs. The flight of aircraft is split into those which locate the target, which then attempt passes, and those which do not locate the specific target, which then loiter during the attack. Let

PLOC = Pr (aircraft locates target), an input to MTOM

ACLOCT = Expected number of aircraft which locate their specific targets

ACL = Expected number of aircraft which do not locate their specific targets

then

$$ACLOCT = (ACR_{old}) (PLOC)$$

and

$$ACL = ACR_{old} (1\text{-}PLOC)$$

Let

AVPL = Expected number of available passes on aircraft which do not locate their specific targets

AVPLOCT = Expected number of available passes on aircraft which locate their specific targets

then

$$AVPL = (AVP_{old}) (1\text{-}PLOC)$$

and

$$AVPLOCT = (AVP_{old}) (1\text{-}PLOC)$$

For the attrition calculations for the ensuing events Eq. 10 through 15 are applied, with the following identifications.

For those aircraft which loiter, the attrition calculations are begun with ACL becoming ACR_{old} and AVPL becoming AVP_{old} in Eq. 10 and 14, respectively. For those aircraft which detect the target, there is one attrition event and ACLOCT becomes ACR_{old} in Eq. 10 and AVPLOCT becomes AVP_{old} in Eq. 14.

When those aircraft which detect their target reach a launch point, additional computations are made. The expected number of passes delivered is computed. This quantity is added to the total passes delivered and subtracted from the passes available. Let

PD = Expected number of passes delivered on mission up to present time

PDLV = Expected number of passes delivered on this attempt

BETA = Pr (aircraft locks-on and tracks), an MTOM input

then

$$PDLV = (BETA) (ACLOCT_{old})$$

$$PD_{new} = PD_{old} + PDLV$$

and

$$AVP_{new} = AVP_{old} - PDLV$$

where $ACLOCT_{old}$ comes from ACR_{new} of Eq. 12, AVP_{old} comes from AVP_{new} of Eq. 14.

Combining. After the calculations are completed for those aircraft which loiter and those which attack their targets, the surviving aircraft are treated as one group. ACR is obtained as:

$$ACR = ACLOCT + ACL$$

and AVP is given by:

$$AVP = AVPLOCT + AVPL$$

This reformed group of aircraft will then proceed to the next set of assigned targets until all assigned targets have been visited, at which time the group returns home. For each of these events the previous equations are applied. When all surviving aircraft have returned home, the final values of the accumulators show ACH, ACK, PD, PH, and PL.

Sortie Survival and Weapons Delivered

To determine sortie survival, let

$$PS = Pr\text{ (aircraft survives sortie)}$$

then

$$PS = \frac{ACH}{XIFS}$$

Also, the MTO/C model needs:

$$RWA = \text{Expected number of weapons delivered per sortie}$$

$$RWA = \frac{(PD)\ (WPNPAS)}{XIFS}$$

where

$$WPNPAS = \text{Number of weapons to be delivered per pass, an MTOM input}$$

MTO/S

MTO/S is the sortie-generation submodel. Maintenance data for the baseline aircraft and for each modification are input to this model by MTOSIN and combined with the results of MTO/P to produce comparative maintenance information. These include probability of damage, the ratio of damage to kill, and the sortie rate–principal output.

Inputs		Outputs
TA	XMMHA	PRDAM
TF	CTU	RDKUSE
TPRF	CTS	SR
TPOF	CTR	TRNRND
TQUE	CTA	
TTAX	PKBASE	
XMMHU	PKMOD	
XMMHS	TS	
XMMHR	PRABR	

To calculate the SR (sortie rate), the DEN (length of a cycle) is calculated. It involves the TRNRND (total delay time), TCMU, TCMS, TCMR, and TCMA (four maintenance times), and the RDK or RDKUSE (damage-to-kill ratio). Each of these is derived and then combined to obtain the SR.

Total Delay Time

Let TRNRND = Total delay time in the absence of maintenance and repair. It is the sum of the following six inputs to MTOM:

TA = Time required to rearm aircraft (clock hours per aircraft)
TF = Time required to refuel aircraft
TPRF = Time required for pre-flight inspection
TPOF = Time required for post-flight inspection
TQUE = Waiting time
TTAX = Taxiing time

Maintenance Times

Clock hours required are computed for four types of maintenance: unscheduled, scheduled, damage and abort repair. Conversion factors are utilized to transform maintenance manhours into clock time.

XMMHU = Manhours required for unscheduled maintenance per flight hour
XMMHS = Manhours required for scheduled maintenance per flight hour
XMMHR = Manhours required to repair a damaged aircraft
XMMHA = Manhours required to repair an aborted aircraft
CTU = Factor for converting XMMHU to clock time
CTS = Factor for converting XMMHS to clock time
CTR = Factor for converting XMMHR to clock time
CTA = Factor for converting XMMHA to clock time

Let

TCMU = Clock time required for unscheduled maintenance per flight hour

TCMS = Clock time required for scheduled maintenance per flight hour

TCMR = Clock time required for damage repair

TCMA = Clock time required to repair aborted aircraft

then

TCMU = (CTU) (XMMHU)

TCMS = (CTS) (XMMHS)

TCMR = (CTR) (XMMHR)

TCMA = (CTA) (XMMHA)

Damage-to-Kill Ratio

The model has two options relative to the damage-to-kill ratio. If IRDK=1, the model automatically sets the damage-to-kill ratio for the modified aircraft equal to the damage-to-kill ratio that was input for the baseline aircraft. This option has an implicit assumption that the probability of a hit on the baseline aircraft, generally, is not equal to the probability of a hit on the modified aircraft.

The other option (IRDK=0) uses the assumption that the probability of hit on the baseline aircraft equals the probability of hit on the modified aircraft. This option implies that the damage-to-kill ratio for the baseline aircraft is not equal to the ratio for the modified aircraft. The balance of this section is devoted to the equations for computing the appropriate damage-to-kill ratio for modified aircraft for the option, IRDK=0. The damage-to-kill ratio for the baseline aircraft is an MTOM input.

The probability of the baseline aircraft being damaged is defined as the product of the ratio of damage-to-kill for the baseline aircraft and PK as:

$$\text{PRDAM(baseline)} = (\text{RDK})\ (\text{PKBASE}) \tag{18}$$

where

PRDAM(baseline) = Pr (baseline aircraft is damaged but not killed, given an attempted sortie)

RDK = Damage-to-kill ratio for the baseline aircraft, an MTOM input

PKBASE = Pr (baseline aircraft is killed, given an attempted sortie), previously calculated in MTO/P

The probability of a hit on the baseline aircraft equals the probability of damage (which implies no kill) plus the PK as:

$$\text{Pr (hit on baseline)} = \text{PRDAM(baseline)} + \text{PKBASE} \tag{19}$$

Combining Eq. 18 and 19 yields:

$$\text{Pr (hit on baseline)} = \text{(RDK) (PKBASE)} + \text{PKBASE} \qquad (20)$$

The probability of hit on the modified aircraft can be written similar to Eq. 19 as:

$$\text{Pr (hit on mod)} = \text{PRDAM(MOD)} + \text{PKMOD} \qquad (21)$$

where

PRDAM(MOD) = Pr (modified aircraft is damaged but not killed, given an attempted sortie)

PKMOD = Pr (modified aircraft is killed, given an attempted sortie), previously calculated in MTO/P.

Rearrangement of Eq. 21 yields:

$$\text{PRDAM(MOD)} = \text{Pr (hit on mod)} - \text{PKMOD} \qquad (22)$$

Since this option uses the assumption that the probability of hit on the modification equals the probability of hit on the baseline aircraft, Eq. 20 and 22 can be combined to yield the computational form

$$\text{PRDAM(MOD)} = [\text{(RDK) (PKBASE)} + \text{PKBASE}] - \text{PKMOD} \qquad (23)$$

The RDKUSE (damage-to-kill ratio for the modified aircraft) is then computed by dividing the value of PRDAM(MOD) from Eq. 23 by the value of PKMOD previously calculated in MTO/P as:

$$\text{RDKUSE} = \text{PRDAM(MOD)/PKMOD}$$

Sortie Rate

Sortie rates are computed as follows:

TS = Duration of sortie (hours), an MTOM input

PRABR = Pr (aircraft aborts), an MTOM input

DEN = Time required per sortie for one cycle consisting of sortie and ground turnaround (hours)

SR = Number of sorties per day (the sortie rate)

This DEN is obtained as the sum of four times. Maintenance due to: sortie length, aircraft combat damage, abort, and total delay. Thus

$$\begin{aligned}\text{DEN} = {} & \text{(TS) (1+TCMU+TCMS) (1-PRABR)} + \text{(TCMR) (PRDAM)} \\ & + \text{(PRABR) (TCMA)} + \text{(TRNRND)}\end{aligned} \qquad (24)$$

and finally

$$SR = \frac{24}{DEN} \qquad (25)$$

MTO/F

MTO/F computes outputs which give the user perspective on the impact of aircraft modifications. This submodel examines the effects of using the baseline aircraft or an aircraft modification over a period of war. For an input TW (time of war) the mission analyzed in MTO/D and MTO/P is carried out at the SR determined by MTO/S. The results of these submodels are extrapolated over the TW to evaluate the measure of effectiveness. During this time period, a specific job is performed (i.e., a specified (input) XNT (number of targets to be attacked) and PRKT (number of passes required to attack each target). The results produced by MTO/F include expected values for sorties completed, passes delivered, targets attacked, and FSR (number of aircraft required for the war).

Inputs	Outputs
TW	SORTAV
SR	SRTPAC
PS	EXTK
PD	FSR
PRKT	PDAC
XIFS	TKAC
XNT	EXSORT
PRABR	EXBA
RDKUSE	PSAB

Derivation of Sorties Per Aircraft

The expected number of sorties one aircraft flies in the TW is an important concept used to determine the FSR. Let

TW = Length of war (in days), an MTOM input

SR = Sortie rate, from MTO/S

SORTAV = Maximum number of sorties attempted by an aircraft in the war

then

$$SORTAV = (TW)(SR)$$

Let

PS = Pr (aircraft survives sortie), an input from MTO/P

SRTPAC = Expected number of sorties attempted by one aircraft, during the time of war. Its derivation is based on the PS and the SORTAV*.

*SORTAV is not necessarily an integer, but for this derivation of the expected value, it is first assumed to be an integer. Then the final equation for SRTPAC is assumed to hold in general.

Also, throughout this section it is tacitly assumed that a function of an expected value can be approximated by the expected value of the function.

For an individual aircraft, the probability it attempts the first sortie is one and the probability it attempts the second sortie is the probability it survived the first, PS. The probability it attempts the (i+1)th sortie (i+1<SORTAV) is the probability it survives the first i sorties, PS^i. Then the expected number of sorties flown by the aircraft is the sum of probabilities of the individual sorties being flown.

$$SRTPAC = 1 + PS + \ldots + PS^i + \ldots + PS^{SORTAV-1} \tag{26}$$

Or summing the geometric series

$$SRTPAC = \begin{cases} \dfrac{(1-PS^{SORTAV})}{1-PS}, & \text{if } PS < 1 \\ SORTAV, & \text{if } PS = 1 \end{cases}$$

Derivation of Required Aircraft

The minimum number of aircraft required to do the fixed job is calculated by using the number of sorties per aircraft, the number of targets attacked per sortie, the length of the war and the number of targets required to be attacked. Let

EXTK = The expected number of targets attacked during the war per aircraft

FSR = The number of aircraft required to complete the wartime job

PDAC = The expected number of passes completed per sortie

TKAC = The expected number of targets attacked per sortie

These are computed from the following four inputs by using SRTPAC of Eq. 26. Let

PD = Passes delivered during mission by one flight, an input from MTO/P*

PRKT = Number of passes required to attack each target, an input to MTOM

XIFS = Flight size, an MTOM input

XNT = Number of targets to be attacked during war, an MTOM input

then

PDAC = PD/XIFS

TKAC = PDAC/PRKT

EXTK = (SRTPAC) (TKAC)

finally

FSR = XNT/EXTK

*On the last sortie the aircraft may be killed before, at, between or after targets. The PD on that sortie, therefore, may be less than on earlier ones. The calculations, in MTO/P, of PD take this into account.

Related Calculations Needed by MTO/C

The MTO/C model requires information on number of: (1) sorties actually flown, (2) damaged sorties, and (3) aircraft surviving the war.

Consider the possibility an aircraft aborts on an attempted sortie. Let

PRABR = Pr (aircraft abort), an MTOM input

and

EXSORT = Expected number of sorties actually flown per aircraft in war

then

$$EXSORT = (SRTPAC)\,(1\text{-}PRABR)$$

where SRTPAC is from Eq. 26. To calculate damaged sorties, let

EXBA = Expected number of damaged sorties per aircraft during war

RDKUSE = Ratio of damages to kills, an input from MTO/S

then

$$EXBA = (1\text{-}PS)\,(RDKUSE)\,(SORTAV)$$

To calculate aircraft survival for the war, let

PSAB = Pr (aircraft survives war)

PS = Pr (aircraft survives sortie), an input from MTO/P

then

$$PSAB = PS^{SORTAV}$$

EVALUATION OF SUB-MOE

Several submeasures of effectiveness are developed (footnote 1). These are quick to evaluate and may be used by a designer of S/V improvements to rank designs. Most such suggested measures involve costs and are presented under *Submeasures of Cost-Effectiveness*. But there is one measure which involves only quantities related to parameters in MTO/E: VA (vulnerable area), payload and gun parameters. Let

VA = Vulnerable area of aircraft ($meter^2$). This is an average VA produced by a weighting of the firing directions from which the defense fire originates.

PL = Payload of aircraft on given scenario (kg)

Using the subscripts "base" and "mod" to stand for baseline and modified aircraft respectively, the index I4 is computed:

$$I4 = \frac{VA_{base} - VA_{mod}}{PL_{base} - PL_{mod}}$$

if

$$I4 \geq \frac{100 - VA_{base}}{PL_{base}}$$

the design modification is worth investigating further. The number 100 in the inequality is a combination of nominal gun parameters.

MTO/C MODEL

STRUCTURE AND OUTPUTS

Some of the input data required by MTO/C are generated by MTO/E, but MTO/C is independent of the other parts of MTOM.

The ultimate output of MTO/C is the present value of the total LCC for a number of aircraft or for the retrofitting of a modification to a number of aircraft of the same type. To maintain consistency and avoid confusion, MTO/C deals with the absolute cost of the force of aircraft, as opposed to the incremental cost due to the modification. Thus, to compare alternative modifications, it is necessary to examine the difference between LCC for the total force with each modification.

There are four component costs which go into the LCC. Each of these is an output of MTO/C. These submodels are:

1. MTO/R (RDT&E)
2. MTO/A (acquisition cost)
3. MTO/G (peacetime O&S (operation and support) cost)
4. MTO/B (additional O&S cost for wartime)

Each of these component costs are incurred over a specified time period and may be discounted to their present value so that their relative importance can be compared more easily. The component costs are discounted, if desired, and integrated over the life cycle by MTO/V (present value model).

The result is the LCC output. Figure 7 displays the structure of MTO/C.

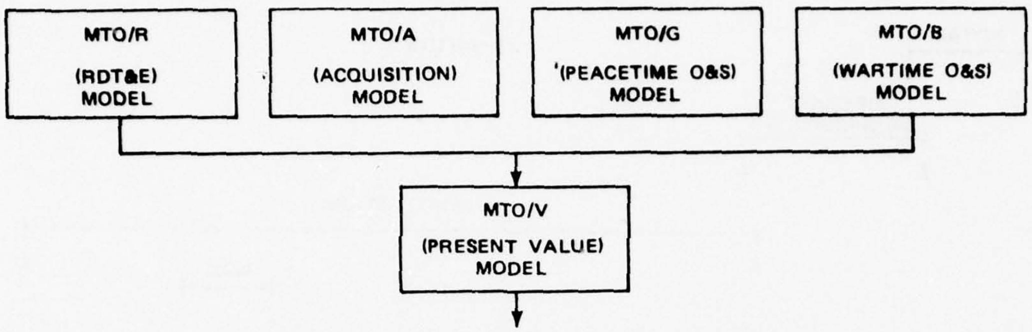


Figure 7. Mission Trade-Off Cost Model.

INPUTS

Aside from inputs obtained from MTO/E, there are three types of inputs required: cost, force sizes and time streams.

The four time periods shown in Figure 8 are part of the input data which must be supplied by the user and should be ordered in a natural manner (e.g., acquisition should not begin prior to the start of the RDT&E period) and illustrates the layout of the time periods for a typical life cycle. There is no reason, however, why the periods should not overlap as long as the ordering is reasonable. If discount rate is input as 0, then only the duration of time periods and not their actual time of occurrence play a role in the calculations.

MTO/R

The RDT&E cost includes all design and development costs, and the cost of the test program for the modification. This cost is entered into the model as a single constant. Thus, C_1 (RDT&E cost) is given by:

$$C_1 = C_R \tag{27}$$

where C_R is the input cost of RDT&E. If the aircraft is the baseline aircraft, C_R presumably will be input as 0.

MTO/A

The cost of acquisition for the modification is calculated in the model as the sum of the cost of modification of existing aircraft plus the cost of purchase for any new aircraft which might be required. The cost of modification is the cost of: (1) modification for the aircraft themselves, (2) any peculiar AGE (associated ground equipment) for the modified aircraft, and (3) initial spares and training for the modified force.

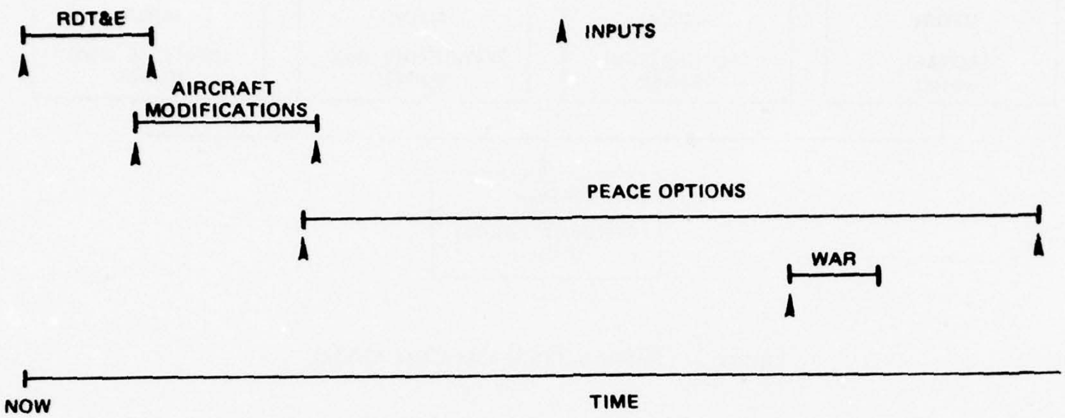


Figure 8. Time Periods for Discounted Life Cycle Costs.

Whether any new aircraft must be purchased is determined by the tentative number of aircraft to be modified entered into the model by the user. The number of aircraft required for the war force is calculated by MTO/E. If the tentative number of aircraft to be modified is greater than the required war force, the model assumes that the extra aircraft are required elsewhere (e.g., another theater of war). Thus, the actual number to be modified is taken as the maximum of these two numbers. If this number to be modified is greater than the total number of aircraft in the force, the model assumes that the difference is made up with purchased aircraft.

The expression for C_2 (acquisition cost) is:

$$C_2 = C_{AK}\, A_{NPUR} + C_{QM/A}\, A_{NGM}\, (1 + r_{HA} + r_{LA}) \tag{28}$$

where

C_{AK} = The cost of a new aircraft

A_{NPUR} = The number of aircraft to be purchased

$C_{QM/A}$ = The cost of modification per aircraft, which may be input as 0 for the baseline aircraft

A_{NGM} = The actual number of aircraft to be modified

r_{HA} = The ratio of the cost of peculiar AGE per aircraft to $C_{QM/A}$

r_{LA} = The ratio of the cost of initial spares and training per aircraft to $C_{QM/A}$

MTO/G

The peacetime O&S cost is calculated for one aircraft on an annual basis. The total peacetime O&S cost is then found by multiplying the annual unit cost by the number of years of peacetime and by the number of aircraft. The resulting equation for C_3 (peacetime O&S cost) is:

$$C_3 = (C_{G/SY}/A_{N/S})\, A_{NG}\, t_{YG} \tag{29}$$

where

$C_{G/SY}$ = O&S cost per squadron per year in peacetime

$A_{N/S}$ = Number of aircraft per squadron

A_{NG} = Total number of aircraft in peacetime force

t_{YG} = Number of years of peacetime operations

MTO/B

The additional O&S cost due to wartime is the sum of five terms:

1. Additional cost due to operating aircraft in theater of war, not including those costs covered in the other four terms
2. Cost of aircraft killed in war
3. Cost of aircraft damaged in war
4. Cost of weapons expended in war
5. Cost of crews lost in war.

This results in the expression for C_4 (wartime O&S cost):

$$\begin{aligned} C_4 = A_{NB}(r_{CBG}(C_{G/SY}/A_{N/S})\, t_{YB}/365 + (1-P_{SAB})\, r_{DAK}\, C_{DK} \\ + (1-P_{SAB})\, C_{AK} + E_{XB/A}\, C_{AX} + E_{SB/A}\, r_{WA}\, C_W) \end{aligned} \tag{30}$$

where

A_{NB} = The number of aircraft in the war force

= FSR, an output from MTO/F

r_{CBG} = The ratio of the change in annual O&S cost due to the war to the annual peacetime O&S cost

t_{YB} = The duration of the war in days

= TW, an input into MTOM

P_{SAB} = The probability an aircraft will survive the war

= PSAB, an output from MTO/F

r_{DAK} = The ratio of crews lost to aircraft killed

C_{DK} = The cost to replace a crew

$E_{XB/A}$ = The expected number of damaged sorties per aircraft in the war

= EXBA, an output from MTO/F

C_{AX} = The cost to repair a damaged aircraft

$E_{SB/A}$ = The expected number of sorties per aircraft flown in the war

= EXSORT, an output from MTO/F

r_{WA} = The number of weapons used per aircraft per sortie

= RWA, an output from MTO/P

C_W = the cost of a weapon

MTO/V

The purpose of the MTO/V submodel is to provide a common basis of comparison for expenditures at different time periods. The mechanism of this common basis is the concept of present value.

Brief Derivation of Discounting Factor

The present value of a single future cost for an interest rate of 10% is given in Figure 9. For example, the circled point on the curve shows that a single \$1 payment due 5 years from now is equivalent to a present expenditure of (\$1) $(1.1)^{-5}$=\$0.62. This is another way of expressing the fact that \$0.62, drawing 10% interest compounded annually will reach \$1 after 5 years.

Figure 10 provides a generalization of the curve in Figure 9, for the case where \$1 cost is paid in N equal annual payments (1/N at each payment). The formula for the curves (Figure 10) for an interest rate of Z percent and N equal annual payments starting after M years in the future, is

$$D = \sum_{i=M}^{M+N-1} \left[\frac{1}{N} \left(\frac{1}{1+0.01Z} \right)^i \right]$$

where

$$10 \geq M+N-1 \geq J$$

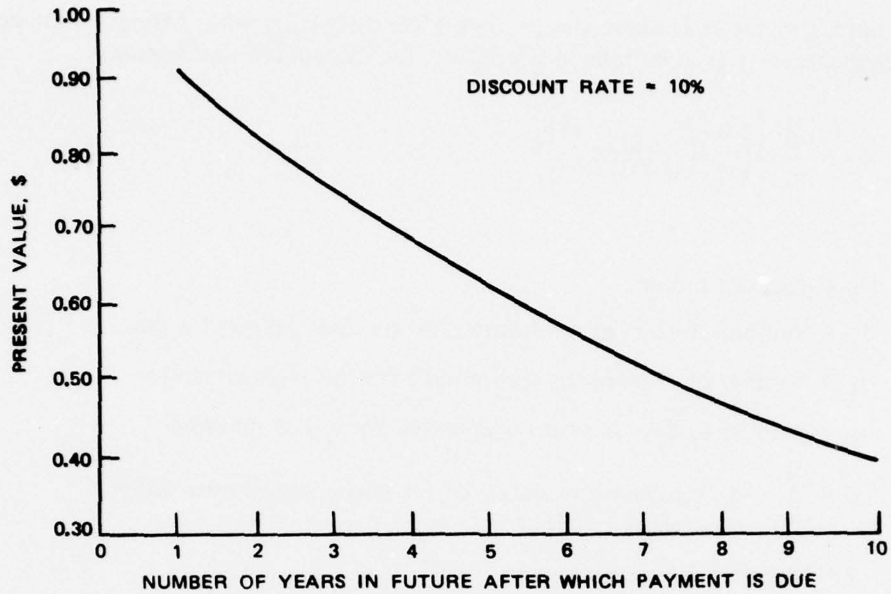


Figure 9. Present Value of a Single Future $1 Payment.

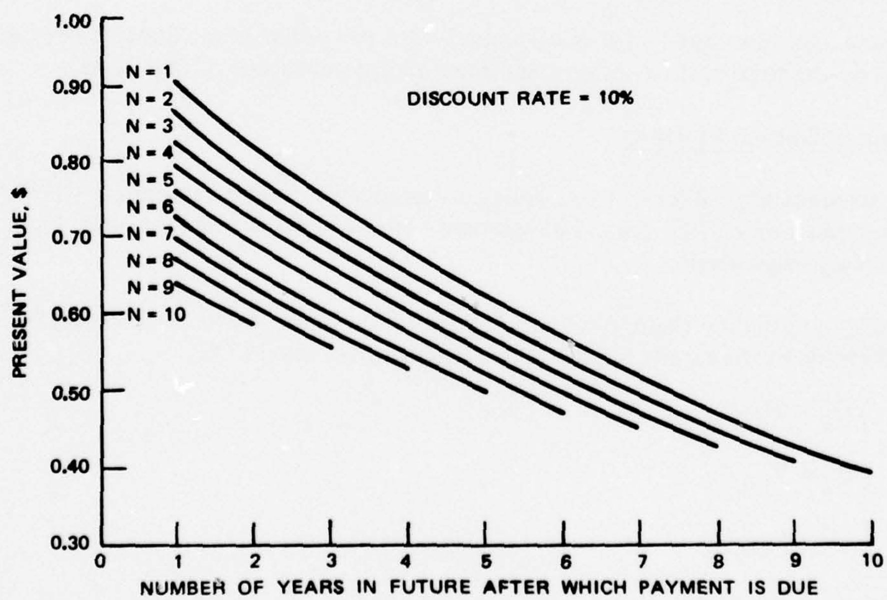


Figure 10. Present Value of N Equal Annual Payments Totaling $1.

In a more general case where the payments are associated with different time periods and the payments start at some time in the future, the discounted cost becomes

$$V_Z = \sum_{i=i_F}^{i_L} \left[\left(\frac{d_i}{D}\right) \left(\frac{1}{1+0.01Z}\right)^i \right]$$

where

V_Z = discount factor

i_F = Number of years in the future until the first payment is due

i_L = Number of years in the future until the last payment is due

d_i = Number of days in year i over which the cost is incurred

$D = \sum_{i=i_F}^{i_L} d_i$, the duration in days of the entire period over which the cost is incurred

Z = Discount rate in percent

For this equation to be valid, i_F and i_L must be integers. To satisfy this condition and still allow for the duration of the time period to be given in days or months, it is assumed that the first payment is due at the end of an integer number of years in the future and that subsequent payments are made at intervals of exactly one year.

Because this discount factor is calculated on a per dollar spent basis, it need only be multiplied by the total cost to obtain the discounted present value of that cost.

Application of Discount Factors

The previous procedure can be applied to calculate discount factors for RDT&E cost, acquisition, peacetime O&S cost, and wartime change in O&S cost to obtain V_{RZ}, V_{QZ}, V_{GZ}, and V_{BZ} respectively.

Finally, combining these discount factors with results for component costs Eq. 27 through 30 leads to the results for the present value of the total LCC.

$$C_1' = V_{RZ}C_1$$

$$C_2' = V_{QZ}C_2$$

$$C_3' = V_{GZ}C_2$$

$$C_4' = V_{BZ}C_4$$

$$LCC = C_1' + C_2' + C_3' + C_4'$$

where

$C_i' =$ Present value of C_i

LCC = Present value of total life cycle cost

SUBMEASURES OF COST-EFFECTIVENESS

The MTOM model computes the following as rough cuts for a designer of S/V improvement programs. The first index consists of the simplified ratio of sortie costs. Let

PK = Pr (aircraft is killed)

= 1-PS

PS = Probability aircraft survives sortie, an input from MTO/P

CAK = Replacement cost of aircraft (assumed equal for baseline or modified aircraft) (same as C_{AK} in MTO/A)

CMQA = Cost of modification of the baseline aircraft (same as $C_{QM/A}$ in MTO/A)

Then index I1* should be ≤ 1 for a proposed aircraft modification to be worth examining further.

$$I1 = \frac{(PK_{mod})(CAK+CMQA)}{(PK_{base})(CAK)}$$

A similar measure can be couched in terms of VA reduction. This measure, which is based upon the exponential relationship between PK and VA, is

$$I2 = \left(\frac{VA_{base} - VA_{mod}}{VA_{base}}\right)\left(1 + \frac{CMQA}{CAK}\right)$$

where VA is the average VA of an aircraft to a particular weapon. VA_{base} and VA_{mod} are MTOM inputs.

$I2 \leq 1$ for desirable aircraft modification

Further manipulation of I2 yields I3, another measure relating VA reduction to costs.

$$I3 = \frac{VA_{base} - VA_{mod}}{CMQA}$$

*I1, 2 and 3 are additional submeasures involving costs

VA_{base}/CAK is constant for all modifications; if $I3 \geq VA_{base}/CAK$ for a given modification, then the modification is in some sense cost-effective. Comparisons of I3 for various modifications result in a method for ranking their desirability.

PARAMETRIC VARIATIONS

INTRODUCTION

Measures

The MTOM model has been exercised to examine the effects of parametric variations. Included are those parameters reflecting aircraft S/V, scenario and target characteristics and those quantifying maintenance procedures. The effects of variations are evaluated by three measures; two are MOE–the number of aircraft lost and the initial number of aircraft required, while the third, O&S cost incurred during war, is a MOC. The measures reflect aircraft performance over a war period during which a specific task or job (attacking targets) is to be performed. (Note: the lower the value of the measure, the better the aircraft effectiveness.)

The effects of various parametric variations are discussed and illustrated. To highlight the sensitivity and to facilitate understanding, the results are normalized with respect to a standard value for each parameter examined. The value of a parameter is expressed as a percent of the standard value; measures of effectiveness and of cost are similarly expressed as percent of the measure obtained using the standard parametric value. This device enables the reader to access the relative importance of a parameter more readily. Usually, only one parameter is varied at a time. Standard values usually selected for the parameters are given in Table 4. The full set of inputs for the standard case is illustrated in the sample output contained in the appendix. The parametric values selected for some of the computer runs are intentionally extreme and sometimes unrealistic. The purpose of using such values is to establish relationships between the parameters and the resulting measures, with minimal regard to the numerical results obtained from the extreme values. However, some parameters reflect sensible information as derived from references 1 through 4.

Parameters

The input parameters (Table 4) fall naturally into general categories. Parameters falling into the category of scenario variation are TW, ATT, XIFS, XNT, and PRKT. Those directly related to aircraft S/V are RDK and VF which quantifies the reduced vulnerability of aircraft modifications. Parameters which reflect the effectiveness of target attacks are PASSRT, PLOC, and BETA. In the category of maintenance variation are SR, TQ, MMHS, MMHU, and MMHD. The parametric analyses for these categories are described later in this report.

Table 4. Parametric Values.

Parameter		Standard value	Variations
TW	(length of war), days	30	15, 60
ATT	(sortie attrition rate)	0.01	0, 0.02, 0.133
XIFS	(initial flight size)	4	2, 8
XNT	(number of targets to be attacked)	40,000	20,000, 80,000
PRKT	(number of passes required to attack target)	2	1, 3
RDK	(ratio of aircraft damages to aircraft kills)	3	2, 4
VF	(vulnerability factors) called B in MTO/D	1.0	0.01, 0.5, 0.8, 0.9, 1.11
Weapons population		1, 2	1, 2, 3, and 1, 2, 3, 4, 5
PSSRT	(number of passes to be attempted per sortie) calculated by MTOM/W	6	4, 5
PLOC	(probability the aircraft locates the target)	0.95	0.5, 1.0
BETA	(probability of successful lock-on and launch)	1.0	0.95
SR	(sortie rate) calculated by MTO/S	1.0	0.74, 0.82, 0.88, 0.94, 0.97, 1.04, 1.07, 1.20, 1.27, 1.55
TQ	(waiting time), hours	10	5, 15
MMHU	(unscheduled maintenance manhours/flying hour)	14.0	7.0, 12.6, 15.4, 28.0
MMHS	(scheduled maintenance manhours/flying hour)	16.0	0, 8.0, 14.4, 17.6, 32.0
MMHD	(manhours/damage repair	600	300, 1200

Relationship Among the Measures

Some discussion of the relationships among two measures will be helpful before discussing the specific cases. The two effectiveness measures are closely related. The following derivation uses equations embedded in the MTOM model, with the indicated approximations MTOMMIE (mini-model of MTOM) results express all relationships in terms

of only one dynamic variable, PSNA. To the extent that (1-PSNA) scales with survivability improvements, MTOMMIE can be used directly not only to shed light on the results of MTOM runs, but also as a rapid evaluation tool for designers and analysts. Let

XNT = Number of targets to be attacked during war period

PRKT = Number of passes required to attack a target

XIFS = Number of aircraft in a flight

PD = Expected number of passes delivered per mission by XIFS aircraft in view of aborts and attrition

NSR = Number of attempted sorties required

then

$$NSR = \frac{(XNT)\,(PRKT)\,(XIFS)}{(PD)} \tag{31}$$

XNT, PRKT, and XIFS are scenario parameters which are MTOM inputs. PD is calculated by MTO/P and reflects the aircraft attrition, aborts, navigational acquisition and lock-on error. An approximation can be introduced for PD to simplify the expression for NSR. Let

PASSRT = Number of passes carried by one sortie, (essentially) an input to MTOM, which may be affected by a vulnerability reduction program

PSNA = Pr (aircraft survives/no abort) which is a function of a vulnerability reduction program and of the dynamics of the scenario

PRABR = Pr (aircraft aborts), an input to MTOM

PNAB = Pr (aircraft does not abort/attempted sortie)

$$= 1\text{-}PRABR \tag{32}$$

then

$$PD \simeq (PASSRT)\,(XIFS)\,(PNAB)\,(PSNA)^{1/2} \tag{33}$$

where the approximation is two-fold; it assumes that the delivery of passes occurs at the midpoint of the attrition and that there are no navigational, acquisition, or lock-on errors. Substituting Eq. 33 into Eq. 32,

$$NSR \simeq \frac{(XNT)\,(PRKT)}{(PASSRT)\,(PNAB)\,(PSNA)^{1/2}} \tag{34}$$

Eq. 33 gives NSR in terms of scenario and aircraft input parameters and only one dynamic variable, PSNA, the complement of the sortie attrition, given no abort.

The SR can be written as:

$$SR = \frac{1}{A+D(1\text{-}PSNA)} \tag{35}$$

where

SR = Sortie rate

A,D = Constants relating to maintenance and turnaround time, derivable from inputs to MTOM. They may be functions of the vulnerability reduction program

A and D can be obtained by manipulating Eq. 18, 24, 25, and 32.

$$A = \frac{1}{24}\left\{\begin{array}{l}(TS)\,(1+TCMU+TCMS)\,(1\text{-}PRABR)\\ +\,(PRABR)\,(TCMA) + (TRNRND)\end{array}\right\}$$

and

$$D = \frac{1}{24}\left\{(RDK)\,(TCMR)\,(1\text{-}PRABR)\right\}$$

Eq. 35 yields SR in terms of scenario parameters, PSNA and maintenance related data which are *functions* of the aircraft modification candidate. Let

TW = Length of war in days, a scenario parameter, an input to MTOM

n = Number of sorties one aircraft can fly in the war if it is not killed

then

$$n = (TW)\,(SR) \tag{36}$$

Note that since n is a function of SR, and SR from Eq. 35 is a function of PSNA, Eq. 36 shows that n also is a function of PSNA and scenario and aircraft inputs to MTOM. Let

SRTPAC = Expected number of sorties attempted by one aircraft during the war

PS = Pr (sortie returns home/attempted sortie)

then

$$PS = (PSNA)\,(PNAB) + (1\text{-}PNAB) \tag{37}$$

and

$$SRTPAC = \begin{cases}\dfrac{1\text{-}PS^n}{1\text{-}PS}, & PS \quad 1\\ n, & PS = 1\end{cases} \tag{38}$$

as can be seen from *MTO/F*.

Using Eq. 37 it can be seen that

$$(1\text{-PS}) = (\text{PNAB})\,(1\text{-PSNA}) \tag{39}$$

Also if PSNA and PNAB are both large,

$$\text{PS} \simeq (\text{PSNA}) \tag{40}$$

Therefore, using expressions Eq. 39 and 40 in Eq. 38 yields the approximation:

$$\text{SRTPAC} \simeq \frac{1\text{-}(\text{PSNA})^n}{(\text{PNAB})\,(1\text{-PSNA})}, \text{PSNA} < 1 \tag{41}$$

a function of PSNA, aircraft maintenance and scenario inputs. We are now ready to obtain expressions for FSR and ACLOST. Let FSR = *number of aircraft required to do job*. Then

$$\text{FSR} = \frac{(\text{NSR})}{\text{SRTPAC}} \tag{42}$$

where if Eq. 31 and 38 are used, the expression is correct (except for approximating an expected value by the ratio of two other expected values), and if the approximations from Eq. 34 and 41 are used Eq. 42 will be an approximation. Let ACLOST = expected number of aircraft lost in the war period. Then

$$\begin{aligned} \text{ACLOST} &= (\text{FSR})\,(1\text{-PS}^n) \\ &= (\text{NSR})\,(1\text{-PS}) \\ &= (\text{NSR})\,(\text{PNAB})\,(1\text{-PSNA}) \end{aligned}$$

Again, this will be correct if the corresponding equations are used for the terms on the right (e.g., Eq. 31 for NSR, etc.) and an approximation if the corresponding approximations are used (e.g., Eq. 34 for NSR, etc.). Now to consider costs, let

$B = *Those O&S costs for a force of aircraft* during war which are in addition to the normal peacetime costs

C = Replacement costs of an aircraft

During war, as attrition increases, the war costs are dominated by C, $\$B \simeq (C)\,(\text{ACLOST})$. As attrition decreases, the quality of this approximation declines since the other quantities involved in $B play a larger role.

MTOMMIE SUMMARY. Collected for easy reference are the approximations which together make up MTOMMIE, the back-of-the-envelope version of MTOM. All approximations are only in terms of PSNA and the eight scenarios and aircraft inputs. Let

$$n = \frac{(\text{TW})}{\text{A+D}(1\text{-PSNA})}$$

then

$$\text{ACLOST} \simeq \left[\frac{(\text{XNT})\,(\text{PRKT})}{\text{PASSRT}}\right] \left[\frac{1\text{-PSNA}}{\text{PSNA}^{1/2}}\right]$$

$$\text{FSR} \simeq (\text{ACLOST}) \left(\frac{1}{1\text{-PSNA}^{n}}\right)$$

and

$$\$\text{B} \simeq (\text{ACLOST})\,(\text{C})$$

where

ACLOST = Expected number of aircraft lost in war period
FSR = Number of aircraft required to do job
$B = Wartime incremental costs
TW = Length of war
A,D = Constants relating to maintenance and turnaround time
PSNA = Probability aircraft survives given no abort
XNT = Number of targets to be attacked
PRKT = Passes required to attack a target
PASSRT = Number of passes carried by one sortie
C = Replacement costs of an aircraft

SCENARIO PARAMETRIC VARIATIONS

TW

The TW parameter is examined at 15, 30, and 60 days. The number of targets attacked remains constant over the varying TW. Sortie and mission probabilities and expected values are equal for the three war lengths. The same number of sorties must be attempted to complete the task (attacking targets) regardless of the TW. Consequently, ACLOST remains constant over TW, $B increases slightly with TW due to FSR changes, but is essentially constant over the range of lengths considered here.

With an attrition rate of 1% aircraft losses are 150 and $B is $680 million. At an attrition level of 13%, losses are 2,420 and costs are $10.6 billion. FSR, however, has a definite relationship to the TW. Figure 11 displays this measure as a function of TW for three levels of attrition, including no attrition. As can be seen, the FSR decreases in each case as the TW increases.

This effect is dependent upon the number of sorties available per aircraft. Clearly this quantity, SRTPAC, increases with the TW. Since as the TW increases, each aircraft flies an increased number of sorties, the total FSR is smaller.

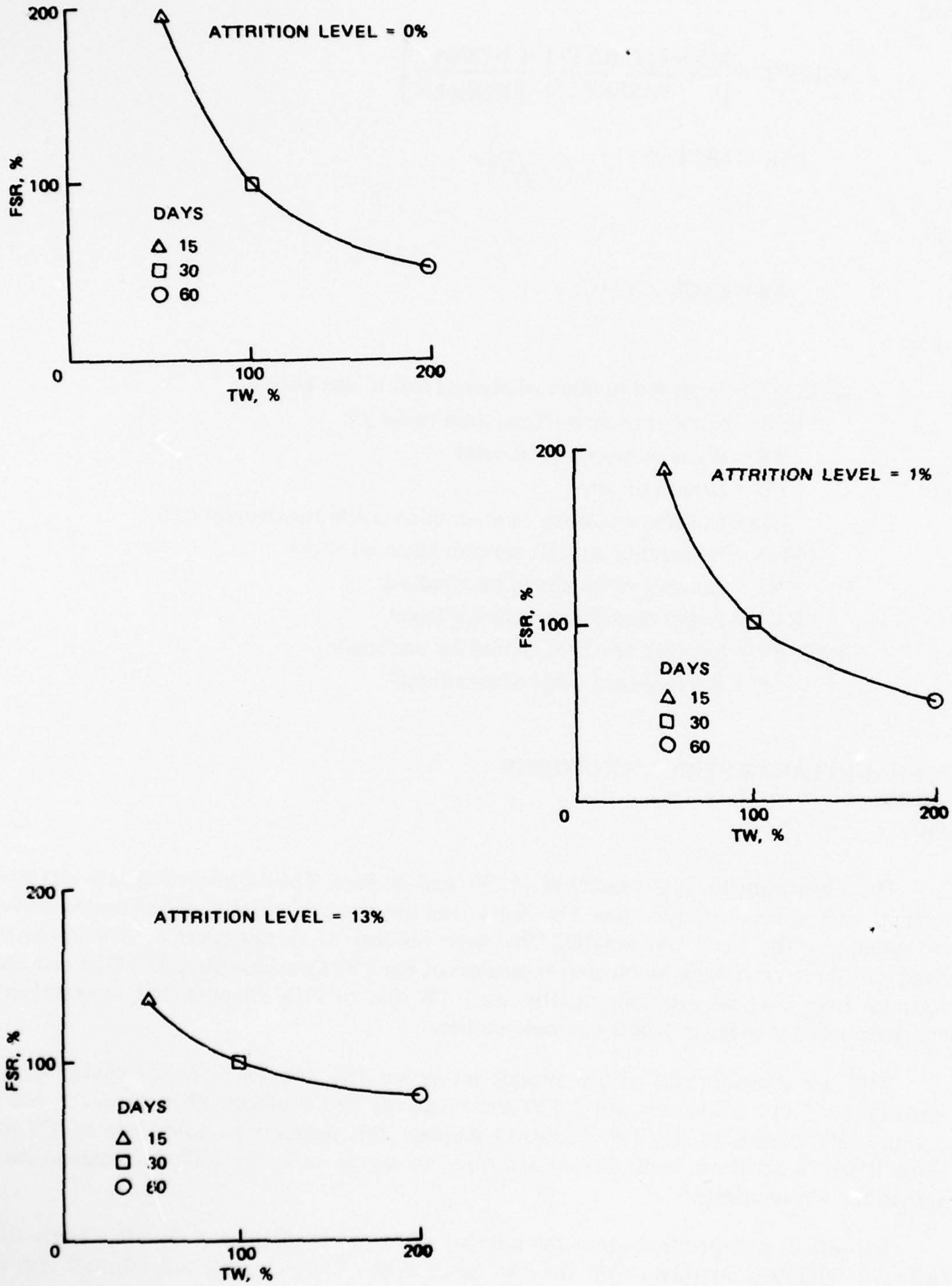


Figure 11. Effect of War Length on Force Size Required.

The equation for FSR as a function of TW is shown, assuming no attrition (PS=1).

$$FSR = NSR/(TW)(SR);\ \text{for } PS=1 \tag{44}$$

By combing Eq. 36, 38, and 42, Eq. 44 shows a true inverse relationship between FSR and TW.

When attrition is considered (PS<1), the relation between FSR and TW is shown as:

$$FSR = (NSR)(1\text{-}PS)/(1\text{-}PS^{(TW)(SR)});\ \text{for } PS<1$$

This equation is also obtained by combining Eq. 36, 38, and 42.

The lower limit of FSR, as TW increases, is:

$$\lim_{TW \to \infty} (FSR) = NSR\,(1\text{-}PS) \tag{45}$$

This limit is approached more rapidly with smaller PS. With higher attrition the relative decrease in FSR associated with a lengthened war is less than that associated with a lower ATT (Figure 11).

ATT

The ATT used for the analysis are 0.01, 0.02, and 0.13. The ACLOST for these levels are 150, 305, and 2,411, respectively. $B are 678, 1,352, and 10,570. The relationship between ATT and ACLOST is very similar although slightly dampened at high levels of attrition as shown in Figure 12. This is because the operating costs of the larger FSR is a smaller component of $B than the replacement costs associated with the aircraft lost at high ATT.

The results for FSR for 0.01, 0.02, and 0.13 ATT are 588, 754, and 3,091, respectively. Figure 13 shows that a certain increase in ATT will result in a smaller proportional increase in FSR than it will in ACLOST.

The FSR is equal to the ratio of ACLOST to the probability a given aircraft fails to survive the whole war, $1\text{-}PSNA^n$. As attrition per sortie increases, the probability that a given aircraft fails to survive the whole war increases, but not as fast. Therefore, FSR increases not quite as fast with attrition as does ACLOST.

XIFS

The effects of three different flight sizes on the measures are evaluated. For this evaluation, an attrition of 13.3% for a flight of four aircraft is used as the standard. (MTOM was run in the absolute attrition mode.) The resulting attrition for a flight size of 2 is 25.4% and 8.2% for a flight size of 8.

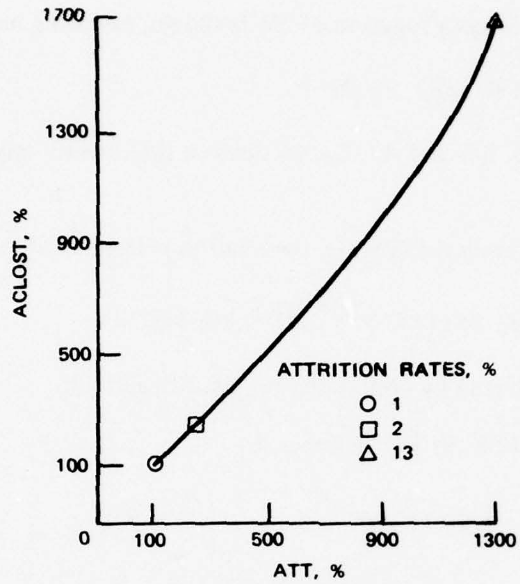


Figure 12. Effect of Attrition Level on Aircraft Lost.

The ACLOST and $B are plotted in Figure 14. Using a flight size of 4, 2,411 aircraft are lost; 5,703 or 237% of standard are lost with a flight size of 2; and 1,178 or 49% are lost with a flight size of 8. $B are 25,001, 10,570, and 5,164 for flight sizes of 2, 4, and 8, respectively. These results are mainly due to the increased sortie survivability associated with increased flight size. This relationship is nonlinear, with aircraft losses and $B increasing more rapidly as flight size decreases. Increasing the flight size reduced $B and number of aircraft killed more and more slowly to the point where Pr (sortie survivability) is virtually one.

The FSR as shown in Figure 15 displays a similar, but somewhat dampened curve; i.e., the changes of flight size do not affect the FSR as dramatically as the other two measures (Figure 14).

By varying vulnerability factors (essentially the attrition), another effect can be examined. Figure 15 also shows that increasing flight size as a method of reducing FSR becomes more effective as the inherent lethality of a situation increases.

XNT and PRKT

XNT (number of targets to be attacked in the war period) and PRKT (number of passes required to attack a target) are discussed together because of their identical relationships with the measures under consideration. Each of these parameters has a simple

multiplicative effect on a measure. Increasing either XNT or PRKT results in an increase in the number of successful passes required during the war period. These variations do not affect sortie survivability or maintenance, but they do impact directly on ACLOST and FSR because of the change in the number of sorties to be flown. The high correlation between $B and ACLOST means the parametric relationship with $B is basically multiplicative also. With attrition fixed at 1%, XNT at 40,000 and PRKT at 2, ACLOST is 150. FSR is 588 and $B is $678 million.

S/V PARAMETRIC VARIATIONS

RDK

The measures are computed with the ratio of damage-to-kill set at 2, 3, and 4 (3 is the standard). Sortie survivability and aircraft capability to deliver passes are not affected by variations in RDK. The effect of varying RDK is to change the probability of aircraft damage. This in turn is reflected in changes in the SR.

Since single sortie effectiveness is unaffected by RDK changes, NSR, (number of aircraft sorties required to perform a given task) is unchanged. Adding the fact that individual sortie survivability is unchanged means that ACLOST remains constant over changes in RDK. Also, since $B is heavily dependent on aircraft replacement cost, this measure basically remains (not absolutely) constant over RDK variations.

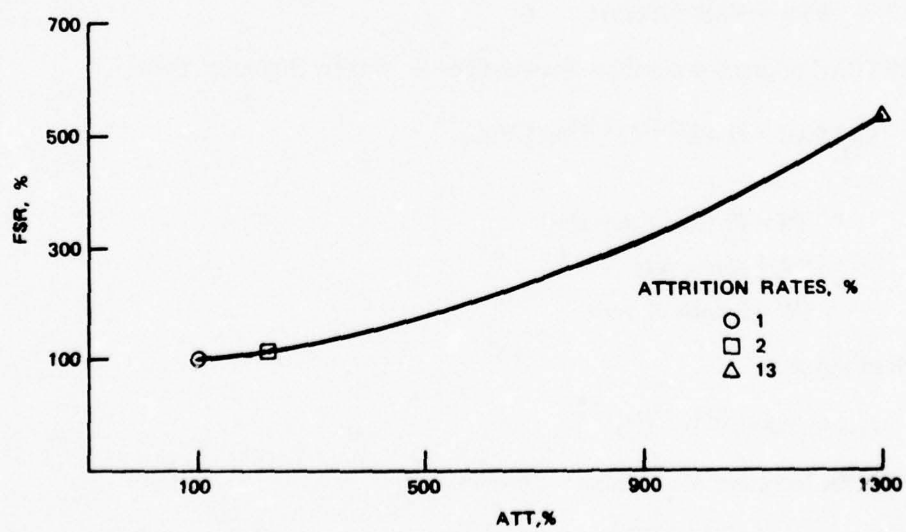


Figure 13. Effect of Attrition Level on Force Size Required.

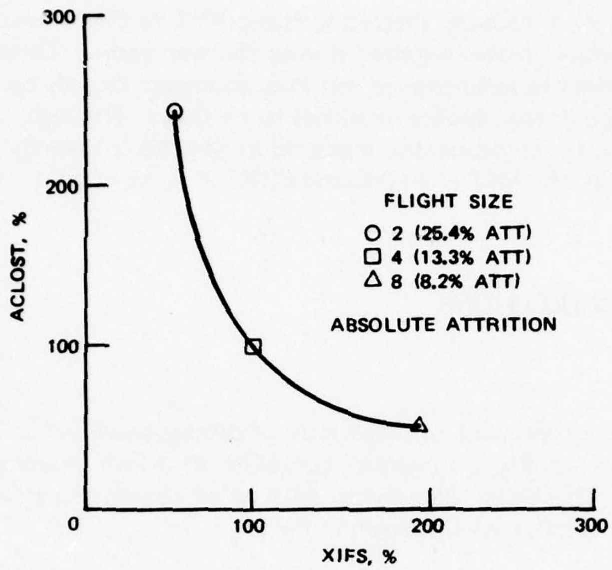


Figure 14. Effect of Initial Flight Size on Aircraft Lost and Wartime Incremental Costs.

The change in SR brought about by RDK variation does affect FSR. This relationship essentially is linear as illustrated in Figure 16. Since NSR is constant, let

$$FSR = NSR/SRTPAC$$

where, SRTPAC (expected number of sorties per aircraft) is changing, then

$$SRTPAC = (1\text{-}PS^{(SR)\,(TW)})/(1\text{-}PS)$$

where

PS = Pr (sortie survival)

SR = sortie rate

TW = length of war

FSR varies then as

$$(1\text{-}PS)/1\text{-}PS^{(SR)\,(TW)})$$

varies. As RSK increase, SR decrease. Consequently,

$$(1\text{-}PS)/1\text{-}PS^{(SR)\,(TW)})$$

and FSR increase.

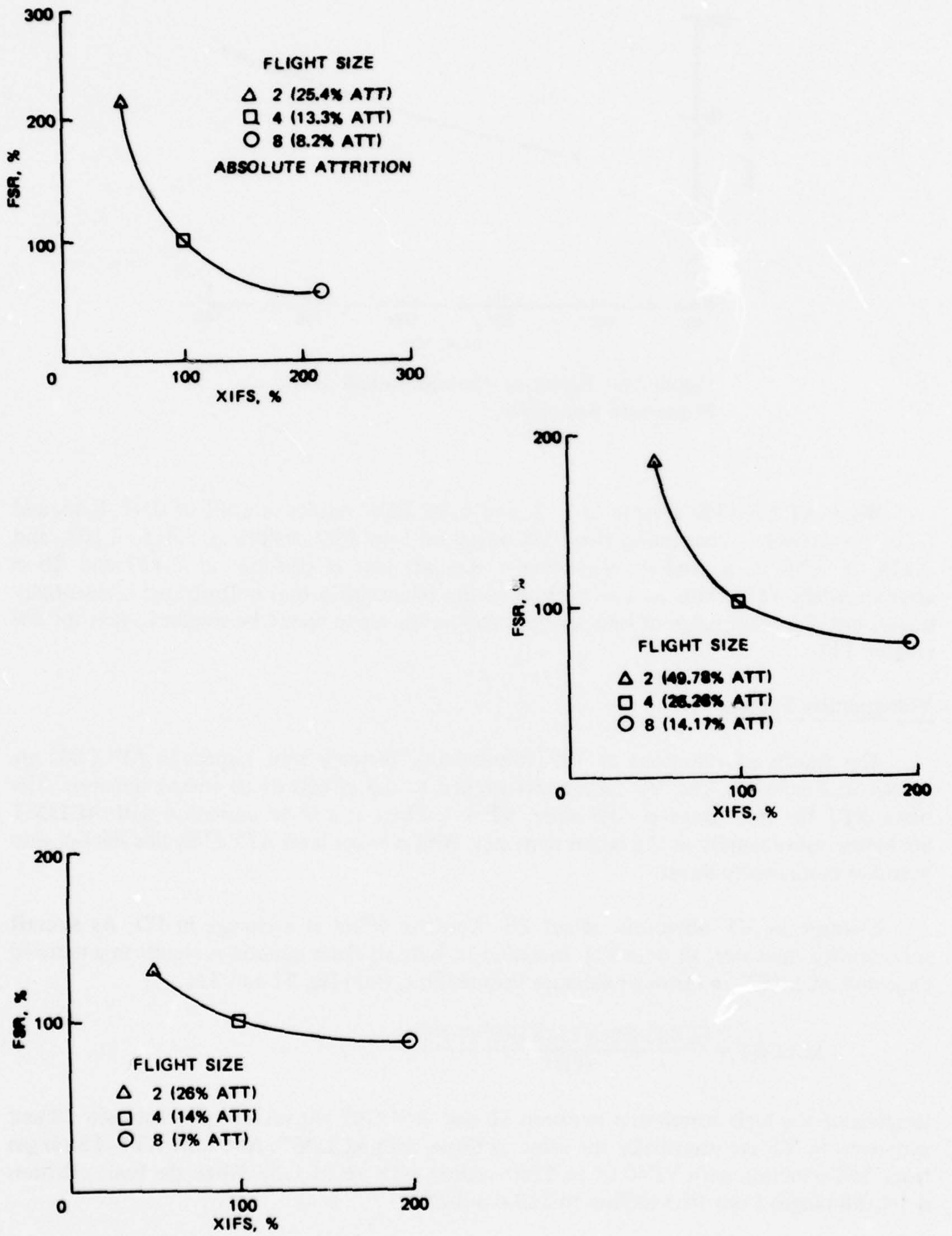


Figure 15. Effect of Initial Flight Size on Force Size Required.

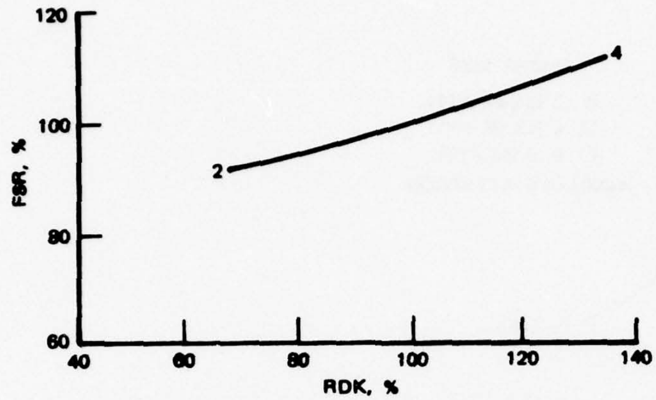


Figure 16. Effect of Damage-to-Kill Ratio on Force Size Required.

When ATT is 13%, a value of 2, 3, and 4 for RDK results in a SR of 0.47, 0.36, and 0.30, respectively. Translating the RDK variation into FSR results in 2,815, 3,103, and 3,418, if RDK=2, 3, and 4, respectively. Aircraft lost is constant at 2,420 and $B is approximately $10.6 billion. The portion of the relationship that is illustrated is essentially linear, but if a wider range of values where shown, the curve would be similar to that for TW (Figure 11).

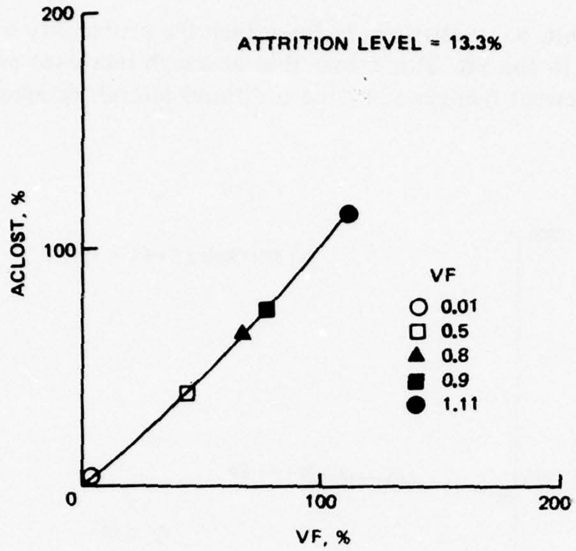
Vulnerability Factors

The results of variations of VF (vulnerability factors) with respect to ACLOST, are shown in Figure 17. The VF factor was applied to the effects of all enemy defenses. The basic ATT for this figure is 13% when VF = 1. There is a slight curvature with ACLOST increasing more rapidly as the factor increases. With a lower level ATT (1%) this relationship becomes more nearly linear.

Changes in VF obviously affect PS. Another effect is a change in PD. As aircraft survivability increases, so does PD. Increases in both of these quantities results in a reduced expected ACLOST. In terms of measure formulation, from Eq. 31 and 33:

$$\text{ACLOST} = \frac{(\text{XNT})\,(\text{PRKT})\,(\text{XIFS})\,(1\text{-PS})}{(\text{PD})}$$

Because of the high correlation between $B and ACLOST the relationship between $B and variations in VF are essentially the same as those with ACLOST. At 13.3% ATT, $B ranges from $48.6 million with VF=0.01 to $750 million with VF of 1.11. When the basic attrition is 1%, $B ranges from $0.3 million to $10.6 million.



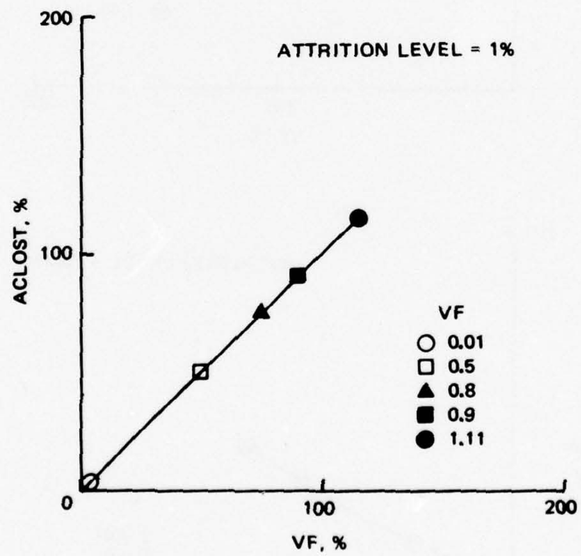


Figure 17. Effect of Vulnerability Factors on Aircraft Lost.

The relationship of FSR to VF is illustrated in Figure 18. ATT at 13.3% displays a higher degree of curvature than 1% ATT. Both of these percentages reveal that the relationship of FSR to the value of a VF is not so direct as that of ACLOST (or $B). Aircraft damage is the key to this dampening effect. Changes in VF do not affect the

probability of aircraft hit. So, if attrition declines, then the probability of damage increases. The result is a decline in the SR. This means that although increased survivability reduces FSR, the effect is somewhat dampened by the additional aircraft needed to compensate for the decreased SR.

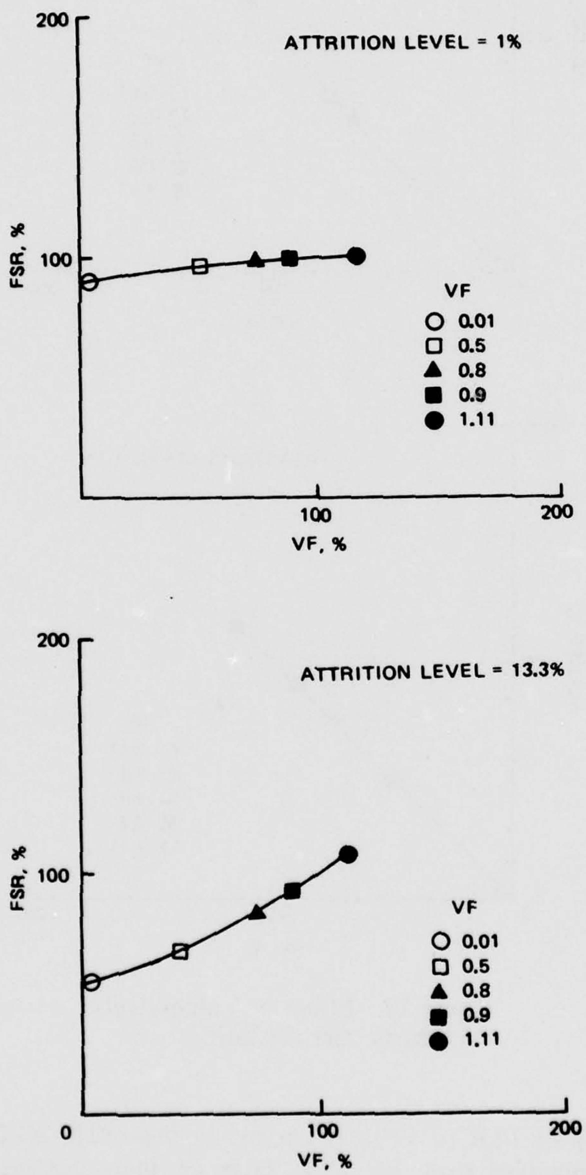


Figure 18. Effect of Vulnerability Factors on Force Size Required.

TARGET CHARACTERISTICS

Defensive Weapon Mix

Survivability improvement programs usually are aimed at reducing aircraft vulnerability to a specific class of enemy weapons. The MTOM model allows the user to examine the effects of such a program with respect to the class of weapons under consideration. In a real life situation the aircraft would be subjected to a broad spectrum of weapon types. MTOM allows the user to also examine the survivability program within the context of the broad spectrum of weapons. The importance of this capability is illustrated by the data in Figure 19. Details of these assumed enemy weapons are presented in the classified supplement (footnote 3). ACLOST is reduced from 150 to 135 (10% reduction) for weapons 1 and 2 only. The vulnerability reduction described has no effect on the lethality of weapons 3, 4, and 5. In this case, the reduction in ACLOST is much smaller than it was in the previous case. ACLOST decreases from 150 to 144. Whereas a 10% reduction in ACLOST is achieved through the vulnerability reduction against weapons 1 and 2 alone, only a 4% reduction in ACLOST occurs when weapons 3, 4, and 5 are present.

An almost identical phenomenon occurs with respect to $B since replacement costs are its major component. Against weapons 1 and 2, $B drops from 679 to 613; but, against all 5 weapons it only drops to 652. The same thing happens to FSR, but on a smaller scale. Against weapons 1 and 2, FSR drops from 588 to 581; but against all 5 weapons it only drops to 585.

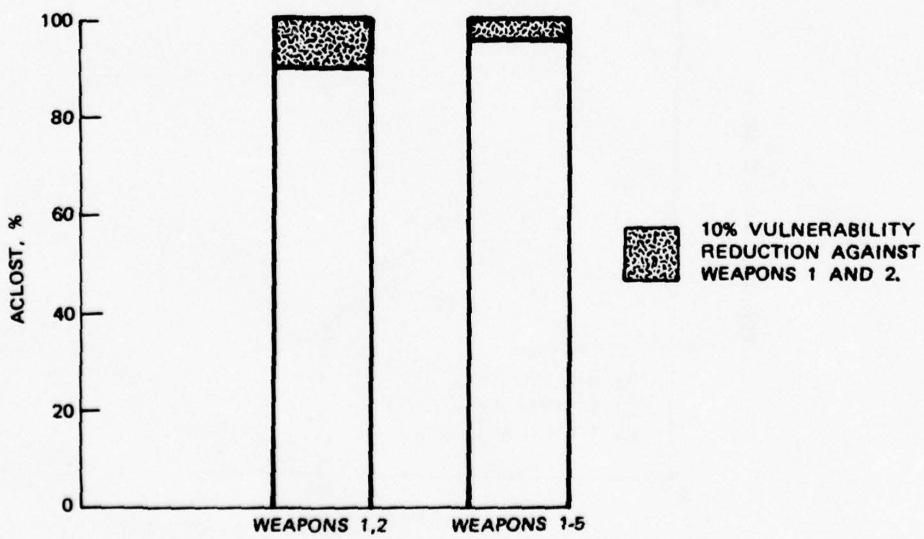


Figure 19. Comparison of Effects From a Vulnerability Reduction.

PASSRT

PASSRT (standard number of passes to be attempted per sortie) is six, two at each of three targets. When five passes are carried, two each are allocated to the first two targets and one to the last. With four passes per sortie, two targets are to be attacked with two passes each.

The results as illustrated by Figure 20 are based on 2.5% ATT for six passes. ATT for four and five passes are 0.75% and 0.96% respectively. The relationship with FSR basically is linear with 792 aircraft required for four passes/sortie, 693 for five and 593 for six. The relationships of ACLOST and $B to PASSRT are different with higher ACLOST and higher values of $B for five passes than for four or six. Expected ACLOST and $B are 167 ($759 million), 173 ($779 million), and 155 ($781 million) for four, five, and six passes, respectively. The differences between four and six passes can be explained in a rather straightforward manner. Clearly, more sorties are required during the war when only four passes are attempted. Despite an increase in sortie survivability for four passes, the increased number of sorties required results in increased values for all measures.

When five passes are attempted, sortie survivability is higher than for six passes, but substantially lower than that for four passes. Consequently, even though fewer sorties are required when five passes are attempted, extrapolation of the lower sortie survivability over the war period results in a larger ACLOST and $B for five passes than that for four passes.

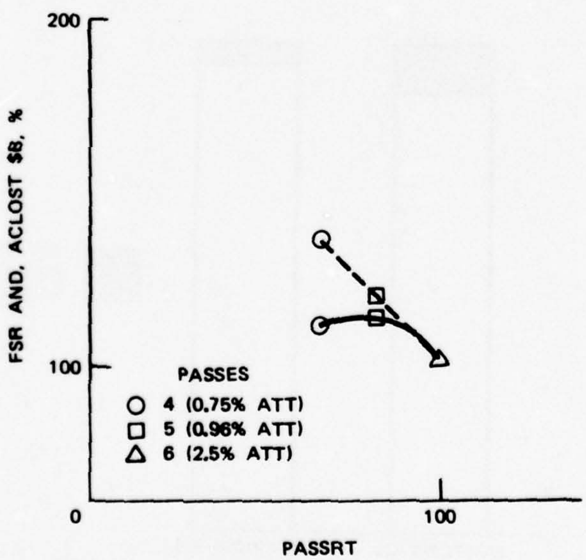


Figure 20. Effects of Passes Per Sortie on Force Size Required, Wartime Incremental Costs, and Aircraft Lost.

The changes in sortie survivability reflect the realistic conditions of the scenario. For these cases the attrition for the baseline aircraft is allocated as:

Defense zone	Percentage
Inbound	10
Target	70
Between target	15
Outbound	5

When the number of passes is reduced, the attrition in the target area and (if the number of targets attacked is changed) between targets is reduced. Inbound and outbound attrition remain the same. The increase in sortie survivability hence is not directly proportional to the reduction in number of passes. If all attrition were allocated to the target areas, then the sortie survivability would be proportional to the reduction in passes. Consequently, aircraft losses would remain virtually constant over the variations in passes.

PLOC

The PLOC (probability of locating a specific target) is varied from 0.5 to 1.0 with 0.95 regarded as the standard case. For these runs, the ATT for the baseline aircraft is 0.01. The values for ACLOST are 315, 155, and 145 when PLOC is 0.5, 0.95, and 1.0, respectively. FSR and $B are 1,149 ($1.404 billion), 593 ($701 million), and 561 ($656 million) as shown in Figure 21.

The figures show that all of the measures possess basically the same relationship to PLOC. With all other factors fixed, the key to these relationships lies in the number of passes delivered. When a target cannot be located the expected number of passes delivered on a sortie (or mission) declines. Consequently, more sorties must be attempted to perform the required task with a larger ACLOST and FSR, and higher costs. Let

$$PD_{0.95} = \text{Expected number passess delivered per mission (PLOC} = 0.95)$$

A good approximation to the magnitude of the effectiveness measures for other values of PLOC can be obtained by simple weighting. If x = new value of PLOC, then

$$PD_x \simeq \left(\frac{x}{0.95}\right)\left(PD_{0.95}\right)$$

Therefore, from Eq. 45

$$ACLOST_x \simeq \left(\frac{0.95}{x}\right)\left(ACLOST_{0.95}\right)$$

and from Eq. 31 and 44

$$FSR_x \simeq \left(\frac{0.95}{x}\right)\left(FSR_{0.95}\right)$$

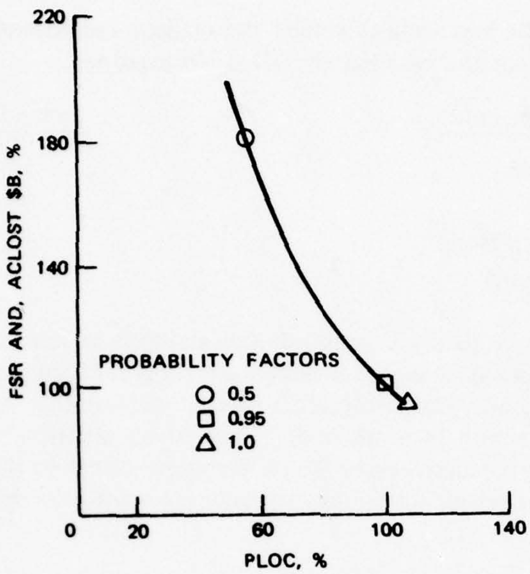


Figure 21. Effects of Probability of Target Acquisition on Force Size Required, Wartime Incremental Costs, and Aircraft Lost.

and from Eq. 43

$$\$B_x \simeq \frac{0.95}{x} \$B_{0.95}$$

Thus, an inverse relationship with PLOC holds for all three measures.

<u>**BETA**</u>

The standard value of BETA (probability aircraft locks-on and tracks) is one. One variation of this parameter, 0.95, results in measures whose values are at 105% of the values when BETA = 1. ACLOST are 155 and 163, FSR is 593 and 624, and \$B is \$701 million and \$737 million. This parameter has the same direct effect on the number of passes delivered as does PLOC above. Therefore, the same types of effects hold with respect to the measures considered here.

MAINTENANCE PARAMETERS

Variations in SR and several other maintenance parameters greatly affect FSR. Since basic sortie survivability and the number of sorties are unaffected by changes in maintenance data, ACLOST remains constant over these changes. \$B, while showing slight fluctuations, remains virtually constant.

SR

SR ranging from 0.75 to 1.55 are illustrated in Figure 22. With a 0.01 ATT, FSR are 758 and 411 for a required SR of 0.75 and 1.55, respectively. The curve indicates that FSR increases more rapidly as SR declines. SR bears the same relationship to FSR as it does to TW.

For example, FSR varies as $\frac{1\text{-PS}}{1\text{-PS}^{(SR)}\ (TW)}$ varies.

Waiting Time, Maintenance Manhours and Damage Repair

Variations in maintenance parameters affect the SR and consequently FSR. These variables have an inverse relationship with SR (i.e., as any of them increases, the SR decreases). The relationships with FSR as shown in Figure 23 are of the opposite nature of that with SR, but basically are linear in character.

Cutting TQ (waiting time for repair) by 50% (standard = 10 hours) reduces FSR by 18% (from 588 to 482). Increasing TQ by 50% increases FSR by 18% (693).

MMH for scheduled and unscheduled maintenance are varied from 50% to 200% for the standard (16 MMH/flying hours for scheduled, 14 for unscheduled). A reduction in MMH of 50% yields a reduction in FSR of 14% (588 to 502). Increasing the maintenance requirements to 200% of the standard results in an increase in FSR of 29% (758) as illustrated in Figure 24.

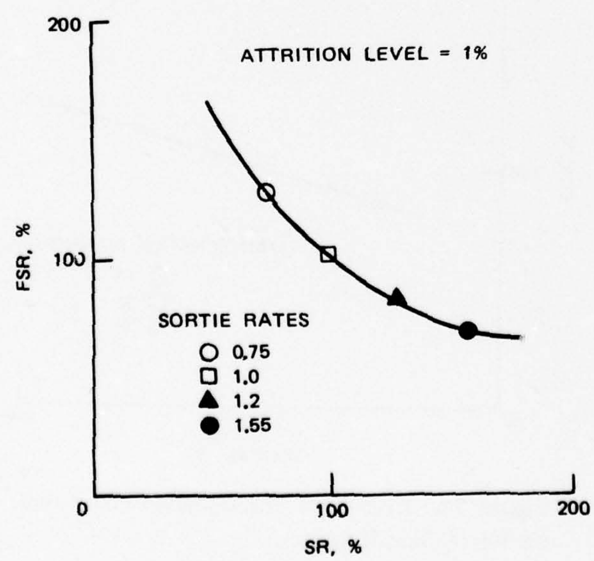


Figure 22. Effects of Sortie Rate on Force Size Required.

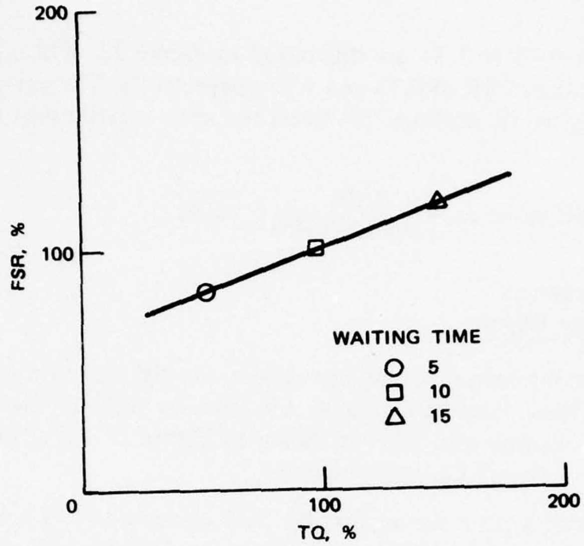


Figure 23. Effects of Waiting Time on Force Size Required.

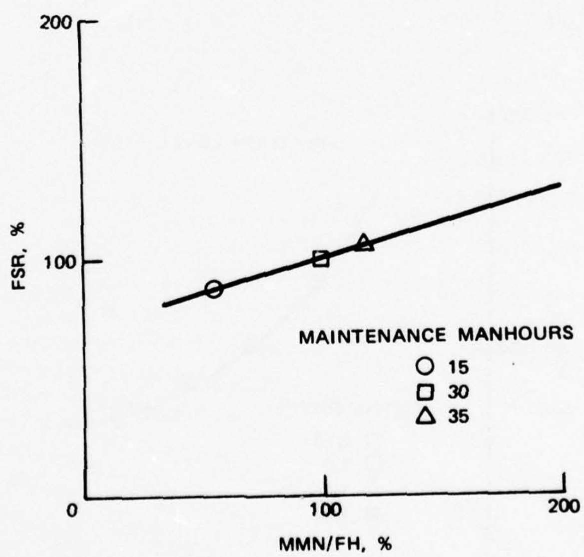


Figure 24. Effects of Maintenance Manhours on Force Size Required.

Deferring all scheduled maintenance is effected by setting the MMH required for scheduled maintenance equal to zero. FSR falls to 70% of the standard under this assumption due to the increased SR.

The effect of changes in damage repair times are shown in Figure 25. A 50% change in damage repair time from the standard (600 hours) results in a 6% change in FSR. It should be noted that probability of damage plays a role in this relationship. If more aircraft are damaged, then the time required to repair them becomes more important in establishing the FSR. The probability of damage for these results is 0.03. A higher probability would result in a steeper slope in the line.

FIXED COST ANALYSIS

MTOM was designed as a fixed effectiveness-variable cost model. That is, a fixed job (e.g., attack 40,000 targets in 30 days) is used as a basis for comparing the relative cost-effectiveness of proposed modifications through the LCC computed for each. It is also possible to use MTOM as a fixed cost model. A graph of the result of several runs of MTOM is all that is needed.

Figure 26 depicts the results of MTOM runs in which the XNT is varied. Thus both effectiveness and costs vary. Plots of XNT versus LCC for the baseline and three hypothetical modifications are shown. The three modifications considered offer 10%, 20%, and 50% vulnerability reductions over the baseline. It is assumed that RDT&E costs and acquisition costs are the same for each of the modifications.

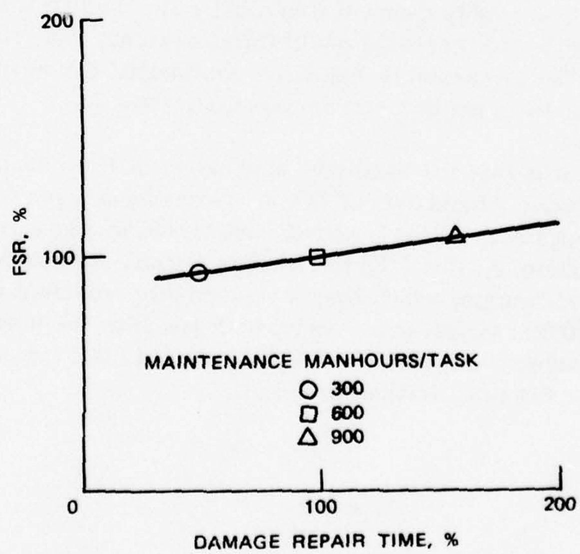


Figure 25. Effects of Damage Repair Time on Force Size Required.

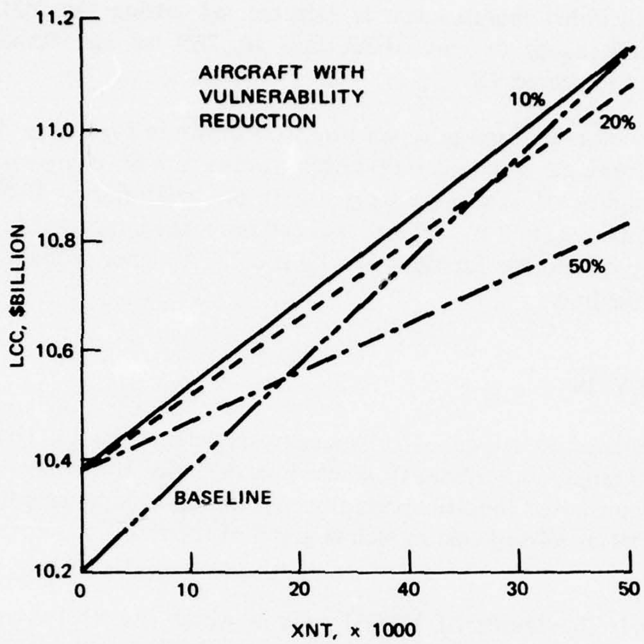


Figure 26. Cost as a Function of Effectiveness for Several Aircraft Vulnerability Reductions.

Two factors become readily apparent from Figure 26. The first is that there is a certain crossover point at which each proposed modification becomes more cost-effective than the baseline. The larger the vulnerability reduction considered, the smaller the effectiveness required before the modification becomes more cost-effective.

The second factor is that the fixed cost application of the model is now possible. The user only needs to choose a fixed level of LCC to determine how much effectiveness (XNT) can be obtained through each of the proposed modifications. For example, choose a fixed cost level of $10.8 billion. At this LCC the baseline aircraft can attack 32,000 targets. The proposed aircraft modifications which have a vulnerability reduction of 10% and 20% can attack 27,000 and 30,000 targets respectively, both less than the baseline aircraft. On the other hand, the 50% vulnerability modification can attack 47,000 targets, far superior to the baseline and the other two modifications in this example.

APPENDIX

LISTING OF PROGRAM OUTPUTS FOR BASIC CASE

The appendix consists of a listing of the output from MTO/E and MTO/C. There are three versions of output from MTO/C displayed. The first is for the standard F-4, while the other two are for hypothetical modifications with the output of the sub-MOE following.

Those data which appear with an asterisk in this appendix are computed intermediate and final results as opposed to user provided inputs.

SAMPLE PROBLEM COMPUTER OUTPUT

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 0 WEAPON 1

ALT	SPEED 30.	61.	91.	152.	213.
152.	.4920	.4500	.4330	.2920	.2000
305.	.4920	.4500	.4330	.3080	.2250
610.	.4670	.4330	.3830	.2920	.2170
1524.	.3830	.3250	.2670	.1750	.1080
3002.	0.0000	0.0000	0.0000	0.0000	0.0000

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 0 WEAPON 2

ALT	SPEED 30.	61.	91.	152.	305.
152.	.4670	.2330	.1000	.0330	0.0000
305.	.4500	.1830	.0830	.0330	0.0000
610.	.4170	.1330	.0500	.0170	0.0000
1402.	0.0000	0.0000	0.0000	0.0000	0.0000
12192.	0.0000	0.0000	0.0000	0.0000	0.0000

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 0 WEAPON 3

ALT	SPEED 30.	61.	91.	152.	305.
152.	.4500	.2000	.1000	.0400	.0050
305.	.6000	.2650	.1450	.0600	.0150
610.	.6000	.2650	.1500	.0650	.0200
1524.	.6000	.2650	.1500	.0650	.0200
3048.	.4500	.2000	.2550	.0400	.0100

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 0 WEAPON 4

ALT	SPEED 30.	61.	91.	152.	213.
152.	0.0000	0.0000	0.0000	0.0000	0.0000
305.	.7910	.6040	.4460	.2480	.1350
610.	.9430	.8190	.7220	.5540	.4190
1524.	.9760	.8930	.8070	.6780	.5590
3048.	.9870	.9040	.8350	.7060	.5930

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 0 WEAPON 5

ALT	SPEED 30.	61.	91.	152.	213.
152.	0.0000	0.0000	0.0000	0.0000	0.0000
305.	.2000	.1890	.1750	.1430	.1070
610.	.9460	.8930	.8180	.6430	.4790
1524.	.9680	.9360	.8930	.7960	.6860
3048.	.9680	.9360	.8930	.8180	.7180

PK TABLE FOR POPUP
MOD 0 WEAPON 1

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.2130	0.0000	0.0000	0.0000
610.	.2080	.2210	0.0000	0.0000
1524.	.1630	.1670	.1630	0.0000
3002.	.1000	.1210	.1080	.0540

PK TABLE FOR POPUP
MOD 0 WEAPON 2

TERM ALT	INIT ALT 152.	305.	610.	1402.
305.	.0250	0.0000	0.0000	0.0000
610.	.0180	.0180	0.0000	0.0000
1402.	.0120	.0120	.0050	0.0000
12192.	.0120	.0120	.0050	0.0000

PK TABLE FOR POPUP
MOD 0 WEAPON 3

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.0380	0.0000	0.0000	0.0000
610.	.0400	.0520	0.0000	0.0000
1524.	.0400	.0520	.0540	0.0000
3048.	.0300	.0410	.0440	.0440

PK TABLE FOR POPUP
MOD 0 WEAPON 4

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.1110	0.0000	0.0000	0.0000
610.	.2600	.3700	0.0000	0.0000
1524.	.3240	.4340	.5840	0.0000
3048.	.3390	.4490	.5990	.6630

PK TABLE FOR POPUP
MOD 0 WEAPON 5

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.0680	0.0000	0.0000	0.0000
610.	.3000	.3680	0.0000	0.0000
1524.	.3840	.4510	.6850	0.0000
3048.	.3960	.4640	.6980	.7800

PK TABLE FOR DIVE
MOD 0 WEAPON 1

ANGLE	INIT ALT 305.	610.	1524.	3002.
15.	.2130	.2080	.1630	.1000
45.	.2130	.2080	.1630	.1000
60.	.2130	.2080	.1630	.1000

PK TABLE FOR DIVE
MOD 0 WEAPON 2

ANGLE	INIT ALT 305.	610.	1402.	12192.
15.	.0250	.0180	.0120	.0120
45.	.0250	.0180	.0120	.0120
60.	.0250	.0180	.0120	.0120

PK TABLE FOR DIVE
MOD 0 WEAPON 3

ANGLE	INIT ALT 305.	610.	1524.	3048.
15.	.0380	.0400	.0400	.0300
45.	.0380	.0400	.0400	.0300
60.	.0380	.0400	.0400	.0300

PK TABLE FOR DIVE
MOD 0 WEAPON 4

ANGLE	INIT ALT 305.	610.	1524.	3048.
15.	.1110	.2600	.3240	.3390
45.	.1110	.2600	.3240	.3390
60.	.1110	.2600	.3240	.3390

PK TABLE FOR DIVE
MOD 0 WEAPON 5

ANGLE	INIT ALT 305.	610.	1524.	3048.
15.	.0680	.3000	.3840	.3960
45.	.0680	.3000	.3840	.3960
60.	.0680	.3000	.3840	.3960

PK TABLE FOR SWING AROUND
MOD 0 WEAPON 1

ALT	
152.	.2000
305.	.2000
610.	.2000

PK TABLE FOR SWING AROUND
MOD 0 WEAPON 2

ALT	
152.	.1250
305.	.1250
610.	.1250

PK TABLE FOR SWING AROUND
MOD 0 WEAPON 3

ALT	
152.	.0270
305.	.0270
610.	.0270

PK TABLE FOR SWING AROUND
MOD 0 WEAPON 4

ALT	
152.	0.0000
305.	.6040
610.	.8190

PK TABLE FOR SWING AROUND
MOD 0 WEAPON 5

ALT	
152.	0.0000
305.	.1890
610.	.8930

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 1 WEAPON 1

ALT	SPEED				
	30.	61.	91.	152.	213.
152.	.4920	.4500	.4330	.2920	.2000
305.	.4920	.4500	.4330	.3080	.2250
610.	.4670	.4330	.3830	.2920	.2170
1524.	.3830	.3250	.2670	.1750	.1080
3002.	0.0000	0.0000	0.0000	0.0000	0.0000

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 1 WEAPON 2

ALT	SPEED				
	30.	61.	91.	152.	305.
152.	.4670	.2330	.1000	.0330	0.0000
305.	.4500	.1830	.0830	.0330	0.0000
610.	.4170	.1330	.0500	.0170	0.0000
1402.	0.0000	0.0000	0.0000	0.0000	0.0000
12192.	0.0000	0.0000	0.0000	0.0000	0.0000

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 1 WEAPON 3

ALT	SPEED 30.	61.	91.	152.	305.
152.	.4500	.2000	.1000	.0400	.0050
305.	.6000	.2650	.1450	.0600	.0150
610.	.6000	.2650	.1500	.0650	.0200
1524.	.6000	.2650	.1500	.0650	.0200
3048.	.4500	.2000	.2550	.0400	.0100

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 1 WEAPON 4

ALT	SPEED 30.	61.	91.	152.	213.
152.	0.0000	0.0000	0.0000	0.0000	0.0000
305.	.7910	.6040	.4460	.2480	.1350
610.	.9430	.8190	.7220	.5540	.4190
1524.	.9760	.8930	.8070	.6780	.5590
3048.	.9870	.9040	.8350	.7060	.5930

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 1 WEAPON 5

ALT	SPEED 30.	61.	91.	152.	213.
152.	0.0000	0.0000	0.0000	0.0000	0.0000
305.	.2000	.1890	.1750	.1430	.1070
610.	.9460	.8930	.8180	.6430	.4790
1524.	.9680	.9360	.8930	.7960	.6860
3048.	.9680	.9360	.8930	.8180	.7180

PK TABLE FOR POPUP
MOD 1 WEAPON 1

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.2130	0.0000	0.0000	0.0000
610.	.2080	.2210	0.0000	0.0000
1524.	.1630	.1670	.1630	0.0000
3002.	.1000	.1210	.1080	.0540

PK TABLE FOR POPUP
MOD 1 WEAPON 2

TERM ALT	INIT ALT 152.	305.	610.	1402.
305.	.0250	0.0000	0.0000	0.0000
610.	.0180	.0180	0.0000	0.0000
1402.	.0120	.0120	.0050	0.0000
12192.	.0120	.0120	.0050	0.0000

PK TABLE FOR POPUP
MOD 1 WEAPON 3

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.0380	0.0000	0.0000	0.0000
610.	.0400	.0520	0.0000	0.0000
1524.	.0400	.0520	.0540	0.0000
3048.	.0300	.0410	.0440	.0440

PK TABLE FOR POPUP
MOD 1 WEAPON 4

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.1110	0.0000	0.0000	0.0000
610.	.2600	.3700	0.0000	0.0000
1524.	.3240	.4340	.5840	0.0000
3048.	.3390	.4490	.5990	.6630

PK TABLE FOR POPUP
MOD 1 WEAPON 5

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.0680	0.0000	0.0000	0.0000
610.	.3000	.3680	0.0000	0.0000
1524.	.3840	.4510	.6850	0.0000
3048.	.3960	.4640	.6980	.7800

PK TABLE FOR DIVE
MOD 1 WEAPON 1

ANGLE	INIT ALT			
	305.	610.	1524.	3002.
15.	.2130	.2080	.1630	.1000
45.	.2130	.2080	.1630	.1000
60.	.2130	.2080	.1630	.1000

PK TABLE FOR DIVE
MOD 1 WEAPON 2

ANGLE	INIT ALT			
	305.	610.	1402.	12192.
15.	.0250	.0180	.0120	.0120
45.	.0250	.0180	.0120	.0120
60.	.0250	.0180	.0120	.0120

PK TABLE FOR DIVE
MOD 1 WEAPON 3

ANGLE	INIT ALT			
	305.	610.	1524.	3048.
15.	.0380	.0400	.0400	.0300
45.	.0380	.0400	.0400	.0300
60.	.0380	.0400	.0400	.0300

PK TABLE FOR DIVE
MOD 1 WEAPON 4

ANGLE	INIT ALT			
	305.	610.	1524.	3048.
15.	.1110	.2600	.3240	.3390
45.	.1110	.2600	.3240	.3390
60.	.1110	.2600	.3240	.3390

PK TABLE FOR DIVE
MOD 1 WEAPON 5

ANGLE	INIT ALT 305.	610.	1524.	3048.
15.	.0680	.3000	.3840	.3960
45.	.0680	.3000	.3840	.3960
60.	.0680	.3000	.3840	.3960

PK TABLE FOR SWING AROUND
MOD 1 WEAPON 1

ALT	
152.	.2000
305.	.2000
610.	.2000

PK TABLE FOR SWING AROUND
MOD 1 WEAPON 2

ALT	
152.	.1250
305.	.1250
610.	.1250

PK TABLE FOR SWING AROUND
MOD 1 WEAPON 3

ALT	
152.	.0270
305.	.0270
610.	.0270

PK TABLE FOR SWING AROUND
MOD 1 WEAPON 4

ALT	
152.	0.0000
305.	.6040
610.	.8190

PK TABLE FOR SWING AROUND
MOD 1 WEAPON 5

ALT	
152.	0.0000
305.	.1890
610.	.8930

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 2 WEAPON 1

ALT	SPEED				
	30.	61.	91.	152.	213.
152.	.4920	.4500	.4330	.2920	.2000
305.	.4920	.4500	.4330	.3080	.2250
610.	.4670	.4330	.3830	.2920	.2170
1524.	.3830	.3250	.2670	.1750	.1080
3002.	0.0000	0.0000	0.0000	0.0000	0.0000

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 2 WEAPON 2

ALT	SPEED				
	30.	61.	91.	152.	305.
152.	.4670	.2330	.1000	.0330	0.0000
305.	.4500	.1830	.0830	.0330	0.0000
610.	.4170	.1330	.0500	.0170	0.0000
1402.	0.0000	0.0000	0.0000	0.0000	0.0000
12192.	0.0000	0.0000	0.0000	0.0000	0.0000

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 2 WEAPON 3

ALT	SPEED				
	30.	61.	91.	152.	305.
152.	.4500	.2000	.1000	.0400	.0050
305.	.6000	.2650	.1450	.0600	.0150
610.	.6000	.2650	.1500	.0650	.0200
1524.	.6000	.2650	.1500	.0650	.0200
3048.	.4500	.2000	.2550	.0400	.0100

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 2 WEAPON 4

ALT	SPEED 30.	61.	91.	152.	213.
152.	0.0000	0.0000	0.0000	0.0000	0.0000
305.	.7910	.6040	.4460	.2480	.1350
610.	.9430	.8190	.7220	.5540	.4190
1524.	.9760	.8930	.8070	.6780	.5590
3048.	.9870	.9040	.8350	.7060	.5930

PK TABLE FOR STRAIGHT AND LEVEL FLIGHT
MOD 2 WEAPON 5

ALT	SPEED 30.	61.	91.	152.	213.
152.	0.0000	0.0000	0.0000	0.0000	0.0000
305.	.2000	.1890	.1750	.1430	.1070
610.	.9460	.8930	.8180	.6430	.4790
1524.	.9680	.9360	.8930	.7960	.6860
3048.	.9680	.9360	.8930	.8180	.7180

PK TABLE FOR POPUP
MOD 2 WEAPON 1

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.2130	0.0000	0.0000	0.0000
610.	.2080	.2210	0.0000	0.0000
1524.	.1630	.1670	.1630	0.0000
3002.	.1000	.1210	.1080	.0540

PK TABLE FOR POPUP
MOD 2 WEAPON 2

TERM ALT	INIT ALT 152.	305.	610.	1402.
305.	.0250	0.0000	0.0000	0.0000
610.	.0180	.0180	0.0000	0.0000
1402.	.0120	.0120	.0050	0.0000
12192.	.0120	.0120	.0050	0.0000

PK TABLE FOR POPUP
MOD 2 WEAPON 3

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.0380	0.0000	0.0000	0.0000
610.	.0400	.0520	0.0000	0.0000
1524.	.0400	.0520	.0540	0.0000
3048.	.0300	.0410	.0440	.0440

PK TABLE FOR POPUP
MOD 2 WEAPON 4

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.1110	0.0000	0.0000	0.0000
610.	.2600	.3700	0.0000	0.0000
1524.	.3240	.4340	.5840	0.0000
3048.	.3390	.4490	.5990	.6630

PK TABLE FOR POPUP
MOD 2 WEAPON 5

TERM ALT	INIT ALT 152.	305.	610.	1524.
305.	.0680	0.0000	0.0000	0.0000
610.	.3000	.3680	0.0000	0.0000
1524.	.3840	.4510	.6850	0.0000
3048.	.3960	.4640	.6980	.7800

PK TABLE FOR DIVE
MOD 2 WEAPON 1

ANGLE	INIT ALT 305.	610.	1524.	3002.
15.	.2130	.2080	.1630	.1000
45.	.2130	.2080	.1630	.1000
60.	.2130	.2080	.1630	.1000

PK TABLE FOR DIVE
MOD 2 WEAPON 2

ANGLE	INIT ALT			
	305.	610.	1402.	12192.
15.	.0250	.0180	.0120	.0120
45.	.0250	.0180	.0120	.0120
60.	.0250	.0180	.0120	.0120

PK TABLE FOR DIVE
MOD 2 WEAPON 3

ANGLE	INIT ALT			
	305.	610.	1524.	3048.
15.	.0380	.0400	.0400	.0300
45.	.0380	.0400	.0400	.0300
60.	.0380	.0400	.0400	.0300

PK TABLE FOR DIVE
MOD 2 WEAPON 4

ANGLE	INIT ALT			
	305.	610.	1524.	3048.
15.	.1110	.2600	.3240	.3390
45.	.1110	.2600	.3240	.3390
60.	.1110	.2600	.3240	.3390

PK TABLE FOR DIVE
MOD 2 WEAPON 5

ANGLE	INIT ALT			
	305.	610.	1524.	3048.
15.	.0680	.3000	.3840	.3960
45.	.0680	.3000	.3840	.3960
60.	.0680	.3000	.3840	.3960

PK TABLE FOR SWING AROUND
MOD 2 WEAPON 1

ALT	
152.	.2000
305.	.2000
610.	.2000

PK TABLE FOR SWING AROUND
MOD 2 WEAPON 2

ALT	
152.	.1250
305.	.1250
610.	.1250

PK TABLE FOR SWING AROUND
MOD 2 WEAPON 3

ALT	
152.	.0270
305.	.0270
610.	.0270

PK TABLE FOR SWING AROUND
MOD 2 WEAPON 4

ALT	
152.	0.0000
305.	.6040
610.	.8190

PK TABLE FOR SWING AROUND
MOD 2 WEAPON 5

ALT	
152.	0.0000
305.	.1890
610.	.8930

WEAPON DENSITY FACTORS AND VULNERABILITY FRACTIONS BY ZONE, A/C MOD AND WEAPON

	ZONE	MOD	WEAPON 1	2	3	4	5
D-FACTOR	1		.0024	.0012	0.0000	0.0000	0.0000
VULN FRACTION		0	1.0000	1.0000	1.0000	1.0000	1.0000
VULN FRACTION		1	.9000	.9000	1.0000	1.0000	1.0000
VULN FRACTION		2	.8000	.8000	1.0000	1.0000	1.0000
D-FACTOR	2		.0120	.0060	0.0000	0.0000	0.0000
VULN FRACTION		0	1.0000	1.0000	1.0000	1.0000	1.0000
VULN FRACTION		1	.9000	.9000	1.0000	1.0000	1.0000
VULN FRACTION		2	.8000	.8000	1.0000	1.0000	1.0000
D-FACTOR	3		.0120	.0060	0.0000	0.0000	0.0000
VULN FRACTION		0	1.0000	1.0000	1.0000	1.0000	1.0000
VULN FRACTION		1	.9000	.9000	1.0000	1.0000	1.0000
VULN FRACTION		2	.8000	.8000	1.0000	1.0000	1.0000
D-FACTOR	4		.0024	.0012	0.0000	0.0000	0.0000
VULN FRACTION		0	1.0000	1.0000	1.0000	1.0000	1.0000
VULN FRACTION		1	.9000	.9000	1.0000	1.0000	1.0000
VULN FRACTION		2	.8000	.8000	1.0000	1.0000	1.0000

NOTE: D-FACTOR = .002 TIMES WEAPON EFFECTIVE RANGE (METERS) TIMES WEAPON DENSITY (QTY/SQ. KM)

ATTRITION OPTION = T   BASELINE A/C ATTRITION   .0100

	1	2	3	4
ZONE WEIGHTING	.1000	.7000	.1500	.0500

SCENARIO PARAMETERS BY A/C MOD

A/C MOD 0	INBOUND DIST	180.	INBOUND TIME	0.
	INBOUND SPEED	200.	INBOUND ALT	1200.
	POPUP TERM ALT	4000.		
	SEARCH DIST	0.	SEARCH TIME	30.
	SEARCH SPEED	230.		
	DIVE ANGLE	30.		
	RET TGT DIST	0.	RET TGT TIME	45.
	RET TGT SPEED	200.		
	OUTBOUND DIST	180.	OUTBOUND TIME	0.
	OUTBOUND SPEED	200.	OUTBOUND ALT	1200.
	LOITER DIST	0.	LOITER TIME	120.
	LOITER SPEED	200.		
A/C MOD 1	INBOUND DIST	180.	INBOUND TIME	0.
	INBOUND SPEED	200.	INBOUND ALT	1200.
	POPUP TERM ALT	4000.		
	SEARCH DIST	0.	SEARCH TIME	30.
	SEARCH SPEED	230.		
	DIVE ANGLE	30.		
	RET TGT DIST	0.	RET TGT TIME	45.
	RET TGT SPEED	200.		
	OUTBOUND DIST	180.	OUTBOUND TIME	0.
	OUTBOUND SPEED	200.	OUTBOUND ALT	1200.
	LOITER DIST	0.	LOITER TIME	120.
	LOITER SPEED	200.		
A/C MOD 2	INBOUND DIST	180.	INBOUND TIME	0.
	INBOUND SPEED	200.	INBOUND ALT	1200.
	POPUP TERM ALT	4000.		
	SEARCH DIST	0.	SEARCH TIME	30.
	SEARCH SPEED	230.		
	DIVE ANGLE	30.		
	RET TGT DIST	0.	RET TGT TIME	45.
	RET TGT SPEED	200.		
	OUTBOUND DIST	180.	OUTBOUND TIME	0.
	OUTBOUND SPEED	200.	OUTBOUND ALT	1200.
	LOITER DIST	0.	LOITER TIME	120.
	LOITER SPEED	200.		

EVENT DEFENSE ZONES

	ZONE
INBOUND	1
POP-UP	2
SEARCH	2
DIVE	2
SWING-AROUND	2
CLIMB TO NEXT PASS	2
CLIMB FOR OUTBOUND	2
BETWEEN TARGET	3
OUTBOUND	4
LOITER DIVE	2
LOITER	2

(* - DENOTES CALCULATED VALUES)

NON-ABORTED FLIGHT SIZE 3.90

* A/C MOD	UNSCALED SURVIVAL PROBABILITY	NO. A/C SURVIVING PER FLIGHT
0	.86706	3.38154
1	.88021	3.43281
2	.89339	3.48420

PT=1. ATTRITION SCALING MAY NOT BE VALID
EVENT = SEARCH

PT=1. ATTRITION SCALING MAY NOT BE VALID
EVENT = SEARCH

PT=1. ATTRITION SCALING MAY NOT BE VALID
EVENT = SEARCH

MISSION TRADE-OFF MODEL
BASELINE AIRCRAFT (MOD 0)

STANDARD F-4 MOD .01 ATTRITION 5 WEAPONS

(* - DENOTES CALCULATED VALUES)

FLIGHT INFORMATION

INITIAL FLIGHT SIZE: 4.

INITIAL NO. OF PASSES PER A/C: 6

NO. OF ASSIGNED TARGETS: 3

NO. OF PASSES PER TARGET

TARGET	PASSES
1	2
2	2
3	2

PROB. OF NO ABORT: .975

PROB. OF NO A/C GNE: .95

PROB. OF A/C FINDING ASSIGNED TARGETS

TARGET	PROB.
1	.95
2	.95
3	.95

PROB. OF A/C LOCK-ON

PASS

TARGET	1	2	3	4	5
1	1.00	1.00			
2	1.00	1.00			
3	1.00	1.00			

NO. OF A/C ABORTS: .100

* NO. OF PASSES DELIVERED (ALL A/C): 21.012

* NO. OF A/C KILLED

.039

* NO. OF PASSES LOST ON A/C KILLED

.120

* NO. OF A/C HOME SAFELY

3.961

* NO. OF PASSES BROUGHT HOME

2.868

MOD 0

* PROBABILITY OF SURVIVAL PER A/C

.99025

* PROBABILITY OF SURVIVAL PER A/C GIVEN NON-ABORT

.99000

* PROBABILITY OF DAMAGE PER A/C

.02925

MAINTENANCE SUMMARY

SORTIE INFORMATION

	UNSCHEDULED	SCHEDULED
MMH/FH	16.0	14.0
CONV.FACT.	.25	.25

	DAMAGE REPAIR	ABORT REPAIR
MMH/TASK	600.0	0.0
CONV.FACT.	.20	.33

TURNAROUND (CLOCK HOURS)

RE-ARM	RE-FUEL	PRE-FLIGHT INSP.	POST-FLIGHT INSP.
.50	.25	.25	.25

WAITING TAXIING

10.00 .16

TOTAL DELAY TIME

11.41

PROB. OF ABORT * PROB. OF KILL

.025 .010

LENGTH OF SORTIE DAMAGE/KILL RATIO

1.10 HRS. 3.00

* SORTIE RATE PER A/C PER DAY

1.00

MOD 0

JOB SCALING FACTORS

NO. TARGETS TO BE ATTACKED=40000.0
LENGTH OF WAR= 30.0 DAYS
NO. PASSES REQUIRED TO ATTACK TARGET= 2.00
INITIAL FLIGHT SIZE= 4.
* SORTIE RATE= 1.00 SORTIES PER DAY
* PROBABILITY OF SURVIVING SORTIE= .99025

JOB SCALING OUTPUT

* MAXIMUM NO. SORTIES AVAILABLE PER A/C IN TW=30.0645
* EXP. NO. SORTIES AVAILABLE PER A/C IN TW=25.9137
* EXP. NO. SORTIES COMPLETED PER A/C IN TW=25.2659
* EXP. NO. TARGETS ATTACKED PER SORTIE=2.626
* EXP. NO. TARGETS ATTACKED PER A/C IN TW= 68.06
* EXP. NO. DAMAGES PER A/C IN TW= .8794
* PROBABILITY OF A/C SURVIVING WAR= .7449
* EXP. NO. A/C LOST IN TW= 149.95

* NUMBER OF A/C REQUIRED TO DO JOB= 587.70

(* - DENOTES CALCULATED VALUES)

MISSION TRADE-OFF METHODOLOGY
COST MODEL

MOD 0

ANNUAL DISCOUNT RATE= 0.00 PERCENT

RDTE COST INPUTS

YEARS/MONTHS TO START OF RDTE= 1/ 0

YEARS/MONTHS TO END OF RDTE= 3/ 0

COST OF RDTE=$ 0.00

ACQUISITION COST INPUTS

YEARS/MONTHS TO START OF ACQUISITION= 2/ 6

YEARS/MONTHS TO END OF ACQUISITION= 5/ 0

NUMBER OF AIRCRAFT IN TOTAL FORCE=1400.

NUMBER OF AIRCRAFT TO BE MODIFIED= 700.

NUMBER OF AIRCRAFT IN WAR FORCE= 587.70

COST OF MODIFICATION PER AIRCRAFT=$ 0.00000

COST OF AGE/COST OF MODIFICATION= .1000

COST OF SPARES/COST OF MODIFICATION= .1000

PEACETIME OPERATION AND SUPPORT COST INPUTS

YEARS/MONTHS TO START OF O+S= 3/ 9

YEARS/MONTHS TO END OF O+S=13/ 9

ANNUAL O+S COST PER SQUADRON=$ 17.49200

NUMBER OF AIRCRAFT PER SQUADRON= 24.

MOD 0

WARTIME OPERATION AND SUPPORT COST INPUTS

YEARS/MONTHS/DAYS TO START OF WAR=10/ 0/ 0

DURATION OF WAR IN DAYS= 30

CHANGE IN ANNUAL O+S COST/ANNUAL PEACETIME O+S COST= .5000

REPLACEMENT COST PER AIRCRAFT KILLED=$ 4.00

CREWS LOST PER AIRCRAFT KILLED= .5800

COST PER AIRCRAFT OF CREW REPLACEMENT=$ .41130

* PROBABILITY AN AIRCRAFT WILL SURVIVE THE WAR= .74485

* EXPECTED DAMAGED SORTIES FLOWN IN WAR PER AIRCRAFT= .88

REPAIR COST PER DAMAGED AIRCRAFT=$ .01840

* EXPECTED SORTIES FLOWN IN WAR PER AIRCRAFT= 25.91

* EXPECTED NUMBER OF WEAPONS USED PER SORTIE= 5.2529

COST PER WEAPON=$ .000195

* PRESENT VALUES--

RDTE COST=$	10.00
ACQUISITION COST=$	168.00
OPERATION AND SUPPORT COST=$	10203.67
CHANGE IN O+S COST FOR WAR=$	549.65
	================
TOTAL LIFE CYCLE COST=$	10931.31

(* - DENOTES CALCULATED VALUES)

SUB-MOES

VA/CAK= 6.2500 (100-VA)/PL= .0250

	I1	I2	I3	I4
MOD 2	.840	1.050	0.000	0.000

DELTA PL=0.0, XI4=DELTA VA

A/C MODIFICATION NUMBER 1

VULNERABILITY FACTOR = .9 OF BASELINE (MOD1 ATT = .9 X BASELINE ATT)

(* - DENOTES CALCULATED VALUES)

FLIGHT INFORMATION

INITIAL FLIGHT SIZE	INITIAL NO. OF PASSES PER A/C
4.	6

NO. OF ASSIGNED TARGETS

3

NO. OF PASSES PER TARGET

TARGET	PASSES
1	2
2	2
3	2

PROB. OF NO ABORT

.975

PROB. OF NO A/C GNE

.95

PROB. OF A/C FINDING ASSIGNED TARGETS

TARGET	PROB.
1	.95
2	.95
3	.95

PROB. OF A/C LOCK-ON

	PASS				
TARGET	1	2	3	4	5
1	1.00	1.00			
2	1.00	1.00			
3	1.00	1.00			

NO. OF A/C ABORTS

.100

* NO. OF PASSES DELIVERED (ALL A/C)

21.022

* NO. OF A/C KILLED

.035

* NO. OF PASSES LOST ON A/C KILLED

.108

* NO. OF A/C HOME SAFELY

3.965

* NO. OF PASSES BROUGHT HOME

2.870

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UNCLASSIFIED JTCG/AS-76-S-001 NL

2 of 2
ADA049 318

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MOD 1

* PROBABILITY OF SURVIVAL PER A/C

.99122

* PROBABILITY OF SURVIVAL PER A/C GIVEN NON-ABORT

.99100

* PROBABILITY OF DAMAGE PER A/C

.03022

MAINTENANCE SUMMARY

SORTIE INFORMATION

	UNSCHEDULED	SCHEDULED
MMH/FH	16.0	14.0
CONV.FACT.	.25	.25

	DAMAGE REPAIR	ABORT REPAIR
MMH/TASK	600.0	0.0
CONV.FACT.	.20	.33

TURNAROUND (CLOCK HOURS)

RE-ARM	RE-FUEL	PRE-FLIGHT INSP.	POST-FLIGHT INSP.
.50	.25	.25	.25

WAITING	TAXIING
10.00	.16

TOTAL DELAY TIME

11.41

PROB. OF ABORT	* PROB. OF KILL
.025	.009

LENGTH OF SORTIE   DAMAGE/KILL RATIO

1.10 HRS.   3.44

DELTA MMH

UNSCHEDULED	0.0
SCHEDULED	0.0
DAMAGE REPAIR	0.0
ABORT REPAIR	0.0

* SORTIE RATE PER A/C PER DAY

1.00

MOD 1

JOB SCALING FACTORS

NO. TARGETS TO BE ATTACKED=40000.0
LENGTH OF WAR= 30.0 DAYS
NO. PASSES REQUIRED TO ATTACK TARGET= 2.00
INITIAL FLIGHT SIZE= 4.
* SORTIE RATE= 1.00 SORTIES PER DAY
* PROBABILITY OF SURVIVING SORTIE= .99122

JOB SCALING OUTPUT

* MAXIMUM NO. SORTIES AVAILABLE PER A/C IN TW=29.9220
* EXP. NO. SORTIES AVAILABLE PER A/C IN TW=26.1857
* EXP. NO. SORTIES COMPLETED PER A/C IN TW=25.5310
* EXP. NO. TARGETS ATTACKED PER SORTIE=2.628
* EXP. NO. TARGETS ATTACKED PER A/C IN TW= 68.81
* EXP. NO. DAMAGES PER A/C IN TW= .9044
* PROBABILITY OF A/C SURVIVING WAR= .7682
* EXP. NO. A/C LOST IN TW= 134.76

* NUMBER OF A/C REQUIRED TO DO JOB= 581.30

(* - DENOTES CALCULATED VALUES)

MISSION TRADE-OFF METHODOLOGY
COST MODEL

MOD 1

ANNUAL DISCOUNT RATE= 0.00 PERCENT

RDTE COST INPUTS

YEARS/MONTHS TO START OF RDTE= 1/ 0

YEARS/MONTHS TO END OF RDTE= 3/ 0

COST OF RDTE=$ 10.00

ACQUISITION COST INPUTS

YEARS/MONTHS TO START OF ACQUISITION= 2/ 6

YEARS/MONTHS TO END OF ACQUISITION= 5/ 0

NUMBER OF AIRCRAFT IN TOTAL FORCE=1400.

NUMBER OF AIRCRAFT TO BE MODIFIED= 700.

NUMBER OF AIRCRAFT IN WAR FORCE= 581.30

COST OF MODIFICATION PER AIRCRAFT=$ .20000

COST OF AGE/COST OF MODIFICATION= .1000

COST OF SPARES/COST OF MODIFICATION= .1000

PEACETIME OPERATION AND SUPPORT COST INPUTS

YEARS/MONTHS TO START OF O+S= 3/ 9

YEARS/MONTHS TO END OF O+S=13/ 9

ANNUAL O+S COST PER SQUADRON=$ 17.49200

NUMBER OF AIRCRAFT PER SQUADRON= 24.

MOD 1

WARTIME OPERATION AND SUPPORT COST INPUTS

YEARS/MONTHS/DAYS TO START OF WAR=10/ 0/ 0

DURATION OF WAR IN DAYS= 30

CHANGE IN ANNUAL O+S COST/ANNUAL PEACETIME O+S COST= .5000

REPLACEMENT COST PER AIRCRAFT KILLED=$ 4.00

CREWS LOST PER AIRCRAFT KILLED= .5800

COST PER AIRCRAFT OF CREW REPLACEMENT=$ .41130

* PROBABILITY AN AIRCRAFT WILL SURVIVE THE WAR= .76817

* EXPECTED DAMAGED SORTIES FLOWN IN WAR PER AIRCRAFT= .90

REPAIR COST PER DAMAGED AIRCRAFT=$ .01840

* EXPECTED SORTIES FLOWN IN WAR PER AIRCRAFT= 26.19

* EXPECTED NUMBER OF WEAPONS USED PER SORTIE= 5.2556

COST PER WEAPON=$ .000195

* PRESENT VALUES--

RDTE COST=$	10.00
ACQUISITION COST=$	168.00
OPERATION AND SUPPORT COST=$	10203.67
CHANGE IN O+S COST FOR WAR=$	613.87
	================
TOTAL LIFE CYCLE COST=$	10995.54

(* - DENOTES CALCULATED VALUES)

SUB-MOES

VA/CAK= 6.2500 (100-VA)/PL= .0250

	I1	I2	I3	I4
MOD 1	.945	1.050	0.000	0.000

DELTA PL=0.0, XI4=DELTA VA

A/C MODIFICATION NUMBER 2

VULNERABILITY FACTOR = .8 OF BASELINE (MOD2 ATT = .8 X BASELINE ATT)

(* - DENOTES CALCULATED VALUES)

FLIGHT INFORMATION

INITIAL FLIGHT SIZE: 4.

INITIAL NO. OF PASSES PER A/C: 6

NO. OF ASSIGNED TARGETS: 3

NO. OF PASSES PER TARGET

TARGET	PASSES
1	2
2	2
3	2

PROB. OF NO ABORT: .975

PROB. OF NO A/C GNE: .95

PROB. OF A/C FINDING ASSIGNED TARGETS

TARGET	PROB.
1	.95
2	.95
3	.95

PROB. OF A/C LOCK-ON

PASS

TARGET	1	2	3	4	5
1	1.00	1.00			
2	1.00	1.00			
3	1.00	1.00			

NO. OF A/C ABORTS

.100

* NO. OF PASSES DELIVERED (ALL A/C)

21.033

* NO. OF A/C KILLED

.031

* NO. OF PASSES LOST ON A/C KILLED

.096

* NO. OF A/C HOME SAFELY

3.969

* NO. OF PASSES BROUGHT HOME

2.871

MOD 2

* PROBABILITY OF SURVIVAL PER A/C

.99220

* PROBABILITY OF SURVIVAL PER A/C GIVEN NON-ABORT

.99200

* PROBABILITY OF DAMAGE PER A/C

.03120

MAINTENANCE SUMMARY

SORTIE INFORMATION

	UNSCHEDULED	SCHEDULED
MMH/FH	16.0	14.0
CONV.FACT.	.25	.25

	DAMAGE REPAIR	ABORT REPAIR
MMH/TASK	600.0	0.0
CONV.FACT.	.20	.33

TURNAROUND (CLOCK HOURS)

RE-ARM	RE-FUEL	PRE-FLIGHT INSP.	POST-FLIGHT INSP.
.50	.25	.25	.25

WAITING	TAXIING
10.00	.16

TOTAL DELAY TIME

11.41

PROB. OF ABORT	* PROB. OF KILL
.025	.008

LENGTH OF SORTIE	DAMAGE/KILL RATIO
1.10 HRS.	4.00

DELTA MMH

UNSCHEDULED	0.0
SCHEDULED	0.0
DAMAGE REPAIR	0.0
ABORT REPAIR	0.0

* SORTIE RATE PER A/C PER DAY

.99

MOD 2

JOB SCALING FACTORS

NO. TARGETS TO BE ATTACKED=40000.0
LENGTH OF WAR= 30.0 DAYS
NO. PASSES REQUIRED TO ATTACK TARGET= 2.00
INITIAL FLIGHT SIZE= 4.
* SORTIE RATE= .99 SORTIES PER DAY
* PROBABILITY OF SURVIVING SORTIE= .99220

JOB SCALING OUTPUT

```
* MAXIMUM NO. SORTIES AVAILABLE PER A/C IN TW=29.7809
* EXP. NO. SORTIES AVAILABLE PER A/C IN TW=26.4592
* EXP. NO. SORTIES COMPLETED PER A/C IN TW=25.7977
* EXP. NO. TARGETS ATTACKED PER SORTIE=2.629
* EXP. NO. TARGETS ATTACKED PER A/C IN TW= 69.56
* EXP. NO. DAMAGES PER A/C IN TW=  .9291
* PROBABILITY OF A/C SURVIVING WAR=  .7920
* EXP. NO. A/C LOST IN TW= 119.61


* NUMBER OF A/C REQUIRED TO DO JOB=  575.00

(* - DENOTES CALCULATED VALUES)
```

MISSION TRADE-OFF METHODOLOGY
COST MODEL

MOD 2

```
ANNUAL DISCOUNT RATE=    0.00 PERCENT

RDTE COST INPUTS

     YEARS/MONTHS TO START OF RDTE= 1/ 0

     YEARS/MONTHS TO END OF RDTE= 3/ 0

     COST OF RDTE=$           10.00


ACQUISITION COST INPUTS

     YEARS/MONTHS TO START OF ACQUISITION= 2/ 6

     YEARS/MONTHS TO END OF ACQUISITION= 5/ 0

     NUMBER OF AIRCRAFT IN TOTAL FORCE=1400.

     NUMBER OF AIRCRAFT TO BE MODIFIED= 700.
```

NUMBER OF AIRCRAFT IN WAR FORCE= 575.00

COST OF MODIFICATION PER AIRCRAFT=$ .20000

COST OF AGE/COST OF MODIFICATION= .1000

COST OF SPARES/COST OF MODIFICATION= .1000

PEACETIME OPERATION AND SUPPORT COST INPUTS

YEARS/MONTHS TO START OF O+S= 3/ 9

YEARS/MONTHS TO END OF O+S=13/ 9

ANNUAL O+S COST PER SQUADRON=$ 17.49200

NUMBER OF AIRCRAFT PER SQUADRON= 24.

MOD 2

WARTIME OPERATION AND SUPPORT COST INPUTS

YEARS/MONTHS/DAYS TO START OF WAR=10/ 0/ 0

DURATION OF WAR IN DAYS= 30

CHANGE IN ANNUAL O+S COST/ANNUAL PEACETIME O+S COST= .5000

REPLACEMENT COST PER AIRCRAFT KILLED=$ 4.00

CREWS LOST PER AIRCRAFT KILLED= .5800

COST PER AIRCRAFT OF CREW REPLACEMENT=$ .41130

* PROBABILITY AN AIRCRAFT WILL SURVIVE THE WAR= .79198

* EXPECTED DAMAGED SORTIES FLOWN IN WAR PER AIRCRAFT= .93

REPAIR COST PER DAMAGED AIRCRAFT=$ .01840

* EXPECTED SORTIES FLOWN IN WAR PER AIRCRAFT= 26.46

* EXPECTED NUMBER OF WEAPONS USED PER SORTIE= 5.2583

COST PER WEAPON=$ .000195

```
* PRESENT VALUES--

                          RDTE COST=$          10.00
                   ACQUISITION COST=$         168.00
        OPERATION AND SUPPORT COST=$        10203.67
        CHANGE IN O+S COST FOR WAR=$          549.65
                                        ================
             TOTAL LIFE CYCLE COST=$        10931.31


   (* - DENOTES CALCULATED VALUES)


                          SUB-MOES

       VA/CAK= 6.2500              (100-VA)/PL=  .0250

                I1            I2            I3            I4

MOD 2          .840         1.050         0.000         0.000

DELTA PL=0.0, XI4=DELTA VA
```

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